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TITLE: THE DEVELOPMENT OF A PORTABLE MODULAR COMPONENT BUILDING SYSTEM FOR THE ARMED FORCES

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SPONSOR: NAVAL FACILITIES ENGINEERING COMMAND system through physical modeling.

The third phase of this program will be conducted in the 692 Professional Study. The objectives of the Professional Study will be to evaluate whether the development goals are met, well defined and feasible; and to insure that the design decisions made are acceptable and justified.

ABSTRACT

A systematic approach is presented for the development of a portable modular component building system for the Armed Forces. The system is designed to meet the long term functional requirements of the military through the use of a modular component system designed to be climate adaptable. The purpose of this paper is to prepare a design program for the concept's design and development in the 692 Professional Study program. The specific objectives of this paper are as follows:

1. Develop specific program criteria and specifications to meet the objectives and goals of such a component building system.
2. Survey the state-of-the-art concepts, building systems and materials meeting the general performance requirements.
3. Select the basic concepts, systems and building materials to be incorporated into a final design geometry and strategy in the 692 Professional Study program.
4. Provide specific program design guidelines the system is to satisfy.
5. Select building functions to evaluate adequacy of design in 692 Professional Study.
6. Select several sites in which to evaluate the

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I. INTRODUCTION

General Statement of Work

The purpose of this report is to develop a building specification for a portable modular component building system for the Armed Services. The system would be capable of meeting the needs of the military by affording a unique flexibility in responding to varied mission requirements. Such a system would provide a readily available shelter system capable of adapting to a variety of climate extremes, while providing a standardized living environment capable of short or long term deployments.

The diversity of mission types demands the Armed Services to be responsive and highly mobile. A sheltering system capable of meeting the Services' needs would increase both their effectiveness and efficiency by providing the occupants with an optimum high quality living environment whereby contributing to the mission's overall success.

Background and Related Work

Currently there are no sheltering systems in the Armed Services' inventory capable of responding to a variety of mission types. Present means of shelter consist mainly of commercially available pre-engineered building systems. These systems generally require time and expertise for their erection and provide austere living environments.

Emphasis generally has been placed on the economy of the system rather than on flexibility and adaptability. The narrow scope of design and construction parameters used to evaluate and design such systems renders no one system capable of meeting the military's total capability needs. The Armed Services continues to show interest in portable sheltering systems through continued evaluation of commercially available systems and technology.

Specific Objectives

The primary objective is to develop a modular portable component building system to meet the short and long term needs of rapid deployment forces. This system would provide a high quality standardized living environment and provide optimum thermal comfort and energy performance throughout a wide climatic range. Finally, such a system would provide optimum user flexibility.

The objectives of this paper are as follows:

1. Survey systems, concepts and materials capable of meeting general performance standards.
2. Develop specific program criteria and design specifications to meet stated objectives.
3. Select systems, concepts and products to be incorporated into final design geometry and strategy.
4. Select specific functions to evaluate the concept's feasibility.
5. Select specific building sites to evaluate whether

the programmed goals were met.

The objectives for the subsequent six (6) hour 692 Professional Study program are as follows:

1. Design a portable modular component building system successfully meeting the program requirements.
2. Evaluate the system through physical modeling of various functional and complexing requirements.
3. To determine if the development goals were met, well defined and feasible.

Scope and Limitations

The scope of this topic shall be limited to the design of a sheltering system to meet the needs of the military. This report provides a survey into current available building concepts, systems and technologies, and identifies their comparative advantages and disadvantages. The needs and parameters of the Armed Services are developed from available Department of Defense publications.

II APPROACH

The literature surveys were conducted in the areas of lightweight building concepts, industrialized building concepts, lightweight material, design and construction, environmental systems and modular design principles. In addition to literature surveys, a mailout questionnaire was solicited to various organizations and commercial building and material manufacturers to better access the available technologies of lightweight building design and related areas. The results of the mailout are indicated in table one (1). The needs of the military were identified and key attributes of a successful shelter system were identified and prioritized. Advantages and disadvantages of available systems, concepts and construction techniques were identified. The building program identifies several criteria attributes required of the system and selects concepts and materials to be used in the design and construction of the system. The building program determines the parameters of the system to be designed in the 692 Professional Study Program.

The History of the Rationalized Building Process

The rationalized building process refers to a systematic design, manufacture and construction process designed to achieve optimum production capacity with a minimum of waste and cost.[1] The term rationalization as applied to the building process refers to methods, techniques and organizations used in the production process. It includes the organization of labor, standardization of materials, products and processes, and simplification of systems of transport and erection. It represented a logical, streamlined building process which relied on industrialized assembly line processes. The primary objective of building rationalization was to provide cost efficient housing for an expanding population.

The origin of a rationalized building process can be traced back to the housing industry and its attempt to meet the needs of a rapidly expanding population during the early 20th century. This process coincided with the development of mass production techniques within the developing automotive industry. The assembly line was a logical means of attaining a standard product at minimal cost with a high degree of regularity and quality. Early proponents of rationalizing the building process such as Arbert Bemis were intent upon modernization of the building industry through the development of standardized building design applied with industrial processes for its manufacture. The evolution of building rationalization was dependent upon the standardized components of uniform dimension, tolerance and size. Rationalization of the housing industry involved the redesign of the physical configuration and organization of typical building systems, structure and construction components, each of which were required to be designed for factory mass production, convenient transport and fast field assembly. Essential for their compatibility with industrial manufacturing methods was their need to be standardized both in form and size. This required the building designers to rethink the traditional design process. Emphasis was required to be placed upon a system of coordination and measurement to obtain standard components which could be used throughout the building.

Standardization of Building Design

Standardization of design represents the starting point of a systematic and rational building process which could achieve new limits of production through uniform design. Standard units of measure were needed to be compatible with industrial methods as well as to provide uniform organization of components. New design methods evolved using a standard module throughout the entire building organization and design.

The standardization of building components was primarily a matter of dimension. Form and size based on a standard module were the first considerations to achieve standard components and regular interfitting relationships and tolerances.

The evolution of a standard planning module developed the use of a cube module. This module offered inherent flexibility of design and interchangeability in three dimensions.

Cubical Modular Design

Cubical modular design in itself simply requires that all parts of the building, particularly the means of interconnection, be apportioned to the same module in three dimensions. The size standardization for uniformity of material dimensions and accuracy of repetitive features such as joints and finishes. Whether the assembly of finished parts is accomplished at the site or in the factory, uniform components provides for interchangeability and flexibility eliminating the need for field cutting and fitting of parts for final site assemblage.

Efforts toward standardization and coordination facilitated field erection by minimizing on site construction time. The benefits of industrialization provides for increased design flexibility, economical production and shorter field erection.

Evolution of Industrialized Building

Industrialized building has come to mean the use of mechanized production line techniques and processes to design and manufacture building components. Industrialization of building encompasses the entire construction process from the planning and design stage to its manufacture and assembly. Assembly line procedures merely provide the means for systematic building process by making possible standardized, mass produced components with precision conformance to necessary tolerances. Modern sophistication of materials and methods has further evolved the art and science of industrialized building. Systems building or prefabrication is the result of industrialization. Prefabrication merely indicates a shifting of work from the building site to the factory. It is, however, a system type of building process. It is reliant on mechanized production techniques which render precise and uniform of the module is determined by practical considerations of materials, structure, transport, assemblage and planning. The standard module deemed most practical during the early inception of modular design rationalization was a 4" (10 centimeters) cube because of its nominal capacity as a most common divisor of the wood frame house.[1] This unit of measure standardized measurements in all three planes of length, width and height. It is imperative, however, that the standard unit of measure be designed according to units of measure compatible with standard units of measure for material dimensions. The standard 4" module developed in the infancy of modular design is still considered the standard design module followed both in the United States and abroad alike.

The Industrialized Mass Production Method

The efforts to standardize the design and manufacture of building components using a modular system of organization provided the essential elements for modernization of the housing industry through mechanized assembly line procedures. Standardization and coordination of components facilitated not only the manufacture of building components but also minimized waste in terms of time and materials. Also, industrial methods provided a uniform standard of quality both in design and construction accuracy. Accuracy of the industrialized building process provided for: elimination of waste and quesswork, continuity of process, uniformity of fabrication, and increased quality control. Essential to industrialized methods was the finishes and products.[2] Thus, the term prefarbication should be viewed as an approach to design, planning and a building delivery system which provides for efficient organization of construction that combines shop fabrication with orderly site assembly. Prefabrication or system building categories are generally classified as follows:

* panel system
* skeletal frame system
* cellular or box system

These categories can be further broken down into more detail, delineating the material composition of the system itself. Each will be discussed further.

Industrialized systems building incorporates a total integration of all subsystems and components into an overall design process fully utilizing industrialized production, transportation and assembly techniques. This integration is achieved using the underlying organizational principles of modular coordination.

Vocabulary of Industrialization

The Module:

For the most part, modular systems and designs are employed within all industrialized building systems. Modular coordination is a system devised to coordinate the sizes of factory made building parts, with the designs of buildings. The modular system is merely a planning device regulating the design and construction planning process on a basis of mathematical ordering principles.

The module has three basic functions:

1. It is the measurement upon which an architectural design is based.

2. It determines the position of the building components within the system and within the building itself.

3. It determines the exact dimensions of each building component.

The Building Component:

The various parts or subsystems of a system called components can be developed in many ways. A component can attain the highest degree of completion at the factory including surface treatments, furnishings and integration of utilities and systems. The industry recognizes five basic categories of components:

1. Components with purely supporting functions.

2. Components with a purely space-partitioning function.

3. Components that unite supporting and partitioning functions.

4. Components that in cell form constitute entire spatial units.

5. Special components (i.e. stairway elements, mechanical elements, etc.)

These components, by their nature and content provide the necessary organization for the system. This is critical due to the nature of systems building from the standpoint of coordination and development of subsystems within the organization.

The terms organizational, technical and planning structures represent central planning concepts for a system's organization of component design.

Organizational Structure: insures steady production and assures desired components are on hand (i.e. component catalogs, codification table, assembly instructions).

Technical Structure: provides for the operational function of the system. This insures that all components correspond and that assembly can proceed without complications. This structure also provides that the climate requirements are met.

The Planning Structure: insures the overall plan is in accordance with the needs of the user and intent of the designer. It insures that the various connection elements of differing functions are coordinated on a planned system and fit together.

These various planning structures provided by the designer for use by the user insure coordination among components and effectively communicates to the user the assembly procedures and requirements. They are used throughout the industry within all current industrialized building concepts.

III. SURVEY OF SYSTEMS BUILDING TECHNOLOGY

There is no single technology applicable to all building situations. There are many traditional methods of construction based on structural principles, materials and methods of environmental control. Industrialization streamlines the building process into an efficient organization that combines modular design practices and shop fabricated components with orderly site assembly. The first step in a systematic design approach to a unique problem is to first consider the available building technologies available to the designer. The attributes of each then should be compared with the user needs to determine the best possible system. The following section provides an overview into current building technologies and approaches which offer potential for portable, lightweight building systems.

The following categories of building approaches are examined:

- Prefabricated Systems
  - Panel Systems
  - Skeletal Frame
  - Cellular or Box Systems
  - Pieces or Special Construction
- Mobile Homes
- Tensile Structures
- Pneumatic Systems
- Site Constructed Systems
- Spray-on Systems

Available industrialized systems provide a wide range of variations in terms of materials, concepts and flexibility of components. The attributes of each are general aspects of the system and are not necessarily limitations of the system. Modifications to each can change their capabilities. This observation is based on the following facts:

1. These approaches are not mutually exclusive nor preclude various mixtures of industrialized processes and/or traditional methods. Concepts can be inclusive and combined to achieve the utmost in design practicability and efficiency in resolving the designer's specific problems.
2. The discovery and implementation of new design methods brought on by current material technology create greater possibilities for each system because of increased structural and material efficiencies.
3. Integration of the above elements can create new possibilities for concepts, component designs and connection details.

For these reasons, no one system is considered optimum or applicable for all conditions. Rather, the required systems performance attributes dictates the selection and necessary modifications of the systems concept.

To determine whether one can take full advantage and use of available and potential technologies, it is vital that all technologies are considered and that they are examined for their potential and constraints; and then determine what must be done to remove such restraints.

Implications of such a total systems approach is the need to integrate the building functions with the following:

1. Structure
2. Environmental Controls
3. Internal Transport
4. Subsystems and Utilities
5. Efficient Construction Operations
6. Maintenance

The extent of integration being dependent upon the strategy of the designer and the needs of the user.

Prefabricated Building Systems

Industrialized or systems building concepts are traditionally classified into four categories: panel, skeletal frame, box or cellular systems and combination systems.

Panel Systems are flat panels having the size of entire wall sections, serving simultaneously as spatial partitions and supporting structure.

Skeletal Frame Systems are systems which spatial partitioning and supporting functions are assigned two different groups of elements. The supporting functions are allotted to a skeletal frame whose perimeters are closed up with non-supporting panels. This system provides greater flexibility of arrangement with a smaller number of different units than a panel system. More joints, however, are usually required than the panel or box systems.

Cellular or Box Systems are fi·:d volume enclosures of room size dimensions. They serve both to enclose volumes and carry loads. These systems strive for the fullest possible incorporation of utilities and finishes to provide a complete, ready living unit.

Pieces or Special Construction Systems represent hybrid combinations of smaller units of panels, columns, beams and floor slabs assembled at the site to provide the structure into which are inserted non-structural panels or field fabricated parts such as partitions.

Each approach represents a variation of the industrialized building process, as such each has comparative advantages and disadvanategs. Generally, the more complete the system, such as cellular systems, the less flexible in arrangement, and variable in volume. Some box design innovations utilize folding elements capable of expanding room volumes. There are many variations of these various themes but their characteristics generally remain the same throughout various modifications.

Characteristics of Industrialized Prefabricated Systems

Cellular or Box Systems

This concept provides for the most complete site ready system. They are further categorized by their degree of self containment and support functions. These two categories are as follows:

A. Lightweight units or mobile home types: Generally they are totally self contained housing units which can retain their mobility or they can be permanently installed by grouping or stacking with the addition of a separate independent demountable frame. In most cases this so called mobile home concept provides for completely preassembled and furnished building volume and requires only on site utility connections for occupancy.

B. Heavyweight or volumetric components: These room size volumes are capable of being grouped horizontally and/or vertically stacked directly to form a variety of multiliving arrangements. This arrangement for direct bearing loads is made possible by the shell construction of concrete, steel sandwich or frames, and/or stressed skinned construction capable of carrying and transferring axial and bending loads. In some cases, these volumes can be incorporated into traditional structural mechanical space grids for highrise capability or can be stacked by checkerboard design, eliminating and avoiding a double walled, six sided structure. Such double walled construction is not an economical use of materials due to repetition of load bearing elements. The attributes of monolithic concepts are:

ADVANTAGES

ATTRIBUTES	DEFINITION
Completeness	Provides the highest degree of a site ready to use living habitat. Units are finished and ready for occupancy.
Integrated	Mechanical systems and subsystems, lighting and utility distribution are integrated and coordinated with each module.
Assembly	Site assembly is minimal. Units need only to be erected and joined.
Joints	Minimal use of joints providing a higher degree of weather integrity.

ADVANTAGES CONTINUED

ATTRIBUTES	DEFINITION
Simple	The concept is simple and straightforward. Units are preassembled and require only interconnection at the site.

DISADVANTAGES

ATTRIBUTES	DEFINITION
Transportable	Monolithic units are restricted in travel capacity due to their weight and large volumes. Systems of this type are more costly to handle.
Erection	Specialized lifting equipment is required to lift and maneuver units. Weight of units precludes man-handling of units.
Flexibility	Systems of this type are usually considered "closed" systems because of their difficult, if not impossible ability to mass volumes in differing ways. Volumes are generally fixed or limited.
Interchange-ability of Components	Cellular units are generally of a complete monolithic construction precluding inter-change of system components if damaged.

Panel

This type of system utilizes large flat panelized unics often large enough to constitute entire wall, roof or floor sections which when site assembled form a building volume. Panel systems are shop fabricated and field assembled and affords the designer a variety of construction methods. They usually have load bearing capacity and come in a variety and range of materials such as concrete termed "heavyweight" systems, to lightweight stress skinned sandwich construction. The characteristics of such a system vary greatly from those of cellular construction. These characteristics or attributes are as follows:

ADVANTAGES

ATTRIBUTES	DEFINITION
Transportable	Systems of this type are less bulky and lighter, allowing for easier transport and containment.
Lightweight	Panels are generally lightweight, affording easy and manageable handling.
Interchangeable	Units are highly standardized and modular affording a high degree of replacement for repair and replacement.

ADVANTAGES CONTINUED

ATTRIBUTES	DEFINITION
Flexibility	Systems of this type depending on their jointing and design, can be highly flexible and allow a variety of arrangements and volumes.

DISADVANTAGES

ATTRIBUTES	DEFINITION
Integration	Panels are not complete, ready to live in assemblies. They require assemblage. Systems and utilities usually must be installed after assemblage of the component system.
Joints	A multiplicity of joints result, possibly impacting its weather integrity. Component jointing tolerances must be closely controlled.
Site Erection	A considerable amount of site assemblage time is required.
Simplicity	System is more complex than a fixed volume. Expertise is required for assemblage.

Skeletal Frame Systems or Pieces

This system utilizes smaller units and components rather than large panels. A skeletal or primary frame system consists of columns and beams, capable of carrying axial and torsional loads which are assembled at the site. Nonstructural panels capable of being inserted within this frame are inserted to provide additional support and loading capability. The objectives of such a system generally are to afford greater flexibility and arrangements with fewer and smaller units to provide a simpler and lighter system requiring limited erection equipment and to design small enough components to be handled by man power alone. The attributes of such a design concept are as follows:

ADVANTAGES

ATTRIBUTES	DEFINITION
Flexibility	Smaller components provide the greatest variety of arrangements and interior volumes.
Handling	Smaller components provide easy erection due to inherent lightness and manageable handling.
Transport	Components are easily transportable due to smaller sizes of panels. System is capable of containerization.

ADVANTAGES CONTINUED

ATTRIBUTES	DEFINITION
Site Adaptable	Smaller components and frame system provides greater inherent capability for adapting to varied site conditions.

DISADVANTAGES

ATTRIBUTES	DEFINITION
Numerous Joints	Smaller system components increase the number and complexity of joints, compromising the weather integrity of the system.
Erection	System requires greater erection efforts at the site for assemblage. Longer erection time is required.
Completeness/ Integration	Subsystems and utilities must be erected after system assembly.
Simplicity	Concept inherently more complex due to a greater number of components, connections and joints.

Tensile Structures

The first system designed for portability was the tensile structure, most commonly referred to as the tent. They were most probably constructed of animal skins and branches. The flexible skins could take up large stresses imposed upon the structure. Only in the last 20 years have the tensile structures such as the suspended roof structures, been used for substantial building purposes. The increased development of this technology has been directly related to improved material membranes such as fiberglass, plastics and synthetic fibers of great strength and elasticity.

Classification of tensile structures are made according to their type of support system. Generally consisting of cables and fabric, tensile structures are lightweight and prestressed to a predetermined amount of tension, providing a definite form of structure. Such structures can be designed to accommodate various external loads such as wind and snow loads and may take on numerous shapes conforming to the designer's intent and volume required.

The science of the tensile structure is complex and diverse and well beyond the scope of this paper. This cursory review of tensile structures shall be limited to the two general types of tensile structures and their relative attributes and characteristics.

All tensile structures have several elements in common. The cables are always in tension and have no inherent stiffness, and the stability of a tensile structure must be achieved soley by a combination of shape and prestressing. The first type of tensile structure is a pole and frame support type structure. This type of tensile structure commonly referred to as a tent structure relies on a central mast to provide support. This type of structure has, by definition, no external force acting upon it because the deadweight of the material membrane is negligible. Because of additional superimposed loads such as wind and snow loads, when applied, requires the structure to still remain in tension. This requires a certain amount of prestressing to restrain these additional loads and to provide and maintain its shape adequately. The sophistication of prestressed fabric structures can vary radically from domes, hyperbolic paraboloids or conical shapes. The variation of each design is determined by the enclosure and dimensional requirements as well as by the aesthetic intent and prestressing requirements brought on by these criteria and environmental and structural requirements.

Another type of tensile structure is the air supported tensile structure. These structures rely on air pressure to inflate and create a volume while relying on the tension cables to provide restraint, support and shape. For large spans, air supported buildings remain one of the most efficient applications of modern fabric structures.

Tensile structures in general are lightweight, collapsible membranes held in tension to carry and transfer loads to supporting or ground holding elements. Such structures have little weight and are of much greater potential as space enclosures where uninterrupted floor space is required. Such systems supply only a protective enclosure from the external environmental elements. The building shell in essence is a lightweight membrane capable only of transferring loads through tension to secondary supporting elements. It is not a total environmental system capable of modifying the interior's environment.

Air Supported Structures

The development of high strength and durable tensile structural membranes has stimulated the growth and use of air supported structures. These structures utilize positive air pressure to provide space enclosure and serve as the primary structural element. These structures, dependent on air pressurization, represent the lightest building systems concept available.

The first proposal for an air supported structure was for improving construction methods for military field hospitals and depots. After World War II the United States Air Force awarded research contracts for the development of a lightweight, fully weather resistant shelter for radar installations. Such systems continue to be used for both military and civilian applications.

The various classification of air structures are: air supported, air inflated and hybrid. The air supported structure is an envelope enclosing a pressurized volume. Air pressure preloads the structure such that it is adequately able to resist externally applied loads without deforming the membrane. The membrane itself or tensile type elements such as cables, serve as primary structural elements.

Air inflated structures consist of self enclosed membranes which are inflated to form cells capable of transmitting applied loads to supports by bending and compression. Hybrid air structures combine elements of both types of systems, sometimes in combination with other structural systems.

Shapes of Air Supported Structures

Air supported structures may be built in a variety of shapes and sizes, depending upon the specific building requirements. Examples of various shapes of unreinforced and cable reinforced air supported structures are as follows:

Domes: In general, they are the most economical form of air supported structures for a given enclosed volume. Domes with circular boundries have been utilized for exhibition functions and for radomes.

Cylindrical Segments: For civilian applications the most popular shape of air supported structure has been the cylindrical segment. Most standard enclosures are of this type.

The concept of integrating the use of an air supported membrane with a rigid enclosure provides increased utility for such technology and systems. For example, steel grids and other rigid support systems could be partially supported by the membrane under pressurization, especially where the infill panels require only lightness or even transluency.

The use of air pressure as a continuous supporting system is not restricted to buildings fabricated of flexible membranes. This concept may be applied to a large variety of shell type structures where internal pressurization may be used to facilitate installation, enhance snow loading resistance and stabilize the structure against high winds. The only requirement is that the fabricated shell be of sufficient low air permeability to permit the development of internal pressure. Air supported structures utilizing materials of high flexibility and strength optimize the salient features of fabric membrane construction which are: ultra-lightweight materials, minimal installation costs and a high degree of potential for easily relocatable structures.

Membrane Characteristics

A common characteristic of most air structure membranes is that they are relatively thin and flexible. Membranes serve not only as a major structural component, but also as a weather seal, exterior finish, interior finish, insulation, wall, roof and if transparent, windows. No one membrane material successfully performs all these functions. Since the membrane serves as the total enclosure, the characteristics of the membrane will dictate the performance of the shelter system. Newer membranes utilize fiber reinforcement for additional strength and durability, while films, coatings or laminates can be applied to extend the life and performance. The characteristics of membrane materials which are significant in determining their application in air supported structures are as follows:

High tensile strength.

Creep or elongation over a period of time, at constant stress.

Low permeability.

Optical properties which vary with the intent of the designer. Membranes can provide for high transluency for daylighting, maximum transmissibility for solar heat gain and opaqueness for cooling.

Thermal Properties: Insignificant contributions to the thermal resistance from the membrane alone. Entrapment of air between membranes increases thermal resistnace.

Acoustic Properties: Excessive reverberation time where special liners are not utilized.

Environmental Resistance: New techniques and materials make air structure membranes as effective as traditional roofing systems. However, ultra-violet exposure results in possible color changes and loss of tensile strength.

Fire Resistance: Low fire resistance ratings. Coated fiberglass membranes provide for noncombustible surface but has very low flexibility.

Summary of Tensile and Air Supported Structures

Air supported structures and pole-frame tensile enclosures are considered together in evaluation because their limitations and advantages are directly related to the membrane's characteristics. While extremely lightweight in design, other elements of their design make these systems inappropriate as a "total systems" approach for this concept. A comparison of the attributes with the critical elements of this concept illustrates this point.

ADVANTAGES

ATTRIBUTES	DEFINITIONS
Lightweight	System is extremely lightweight and highly portable.
Erection	System capable of fast erection.
Transportable	System is highly transportable due to little or no bulk or cubage.

DISADVANTAGES

ATTRIBUTES	DEFINITION
Flexibility	Not flexible. Can enclose large volumes well, but interior spaces cannot be separately enclosed.
Simplicity	Erection and assembly must be done by personnel with prior experience due to the multitude of supports and proper tensioning.
Completeness	Mechanical, plumbing, electrical and utility distribution; not integrated, must be accomplished after erection. Separate systems and materials are required.
Environmental Performance	Limited thermal resistance and capacity. Separate heating and cooling systems are required.
Site Adaptable	Building site required to be well prepared and flat. No floor system is provided with the enclosure.

Summary

System does not meet the objectives and goals of the building concept. Fabric membranes provide limited capabilities of performance. Systems of this type require continuous supporting equipment for pressurization (if air supported) and/or fails to supply a holistic design strategy capable of rapid erection, demounting and containerization. Installation of separate building elements such as interior walls, doors, lighting and mechanical systems renders this system impractical for this intended concept.

Mobile Home Concept

The design of the mobile home is governed by the objective to provide a fully furnished primary housing unit that can be transported from the factory to the eventual building site. The design criteria of the mobile home is essentially the same as those of conventional housing aside from the requirement of transportability. The major differences of mobile home design lies within the construction of the unit itself. The mobile home is unique in that it utilizes a structural box design which allows for thinner wall construction. They are engineered to restrict in-transit, erection and on site loads. These loads are distributed throughout the stressed skin and transferred to the chassis. The principles embodied in mobile home construction applicable toward this concept are as follows:

1. Mobile homes use a stressed skin system to carry loads resulting in thin light cross sections.

2. The mobile home is designed to absorb the stresses as an entire unit, thus employing a unibody construction.

3. The mobile home is dependent on the chassis to carry a portion of the floor loads.

The mobile home concept is a viable building concept specifically tailored for a highly portable sheltering system. This system incorporates the mobility requirement along with the building concept. These structures rely on a unibody construction principle which restricts their expansion capability and flexibility. However, this in part is overcome by the delivery of a ready to use system. The characteristics of this concept are summarized below:

ADVANTAGES

ATTRIBUTES	DEFINITION
Completeness	Unit is complete and ready to occupy. No work at site is required except utility connections.
Erection	No erection is required.
Transport	Units are transportable by air, sea and land.
Simple	Concept is simple and straightforward.

DISADVANTAGES

ATTRIBUTE	DEFINITION
Flexibility	Units are fixed volume containers. Spaces are determined at the factory, not by the occupant/user. Units are separate, requiring a connecting module.
Local Moving	Units are extremely heavy. Special equipment is required to handle and maneuver units.
Transport	While this system is capable of transport, its fixed volume and weight restrict its travel capacity in comparison to the panelized or skeletal frame system. This is not considered efficient because of its large, empty cubage capacity.
Site Adaptable	Units require level site unless leveling jacks are available.
Interchange-ability and Repair	Units rely on stressed skin unibody construction. Repair is difficult when damage occurs because of the lack of interchange-ability of component parts.

Site Constructed Systems - Sprayed-on Building Enclosures

A more exotic system of fabricating permanent or temporary shelter is the use of the spray-on systems. Based on a newer developing technology, these systems utilize sprayed plastic or concrete materials usually reinforced with glass fibers over a constructed or inflated formwork. No shop fabricated components are required, rather, specialized spray equipment and bulk materials are needed at the site.

The relative simplicity of their design and farbication make them a cost effective means of constructing various shelter types.

This construction system is, however, severely restricted for its application in this concept based on the following:

ADVANTAGES

ATTRIBUTES	DEFINITION
Economy	System is cost effective.

DISADVANTAGES

ATTRIBUTES	DEFINITION
Completeness	System is incomplete with regards to interior partitioning and utilities. Mechanical systems and utility distributions must be provided for separately at the site, after the structure is erected.

DISADVANTAGES CONTINUED

ATTRIBUTES	DEFINITION
Portable	System is not reusable or portable.
Transport	Bulk materials require transport. Specialized equipment is necessary.
Flexibility	Concept does not permit design flexibility. Structures are usually dome structures.

Summary of Attributes for Industrialized and Lightweight Building Concepts

Optimum ○

Good ◒

Adaptable ⦶ Limited ●

	Speed of Erection	Complexity of Erection	Transport	Field handling	Flexibility	Completeness	Compactness	Environmental Performance	Habitability
Prefabricated									
Box	○	◒	●	●	⦶	◒	○	⦶	⦶
Panel	●	⦶	◒	◒	◒	⦶	⦶	⦶	⦶
"Pieces"	●	●	◒	◒	◒	⦶	⦶	⦶	⦶
Tension									
Pole & Frame	●	●	◒	◒	●	●	●	●	●
Air Supported									
Air Inflated	○	○	○	○	●	●	○	●	●
& Air Supported									
Pre-engineered Systems	●	⦶	◒	◒	●	⦶	⦶	⦶	⦶
Spray on Systems	⦶	◒	◒	◒	●	●	●	●	●

IV. STATUS OF MATERIAL TECHNOLOGY FOR LIGHTWEIGHT BUILDING SYSTEMS

The characteristics of the various materials incorporated within the design will, in part, determine or contribute to the following:

1. Economy
2. Durability
3. Lightness
4. Maintenance
5. Integrity of Joints
6. Longevity
7. Strength
8. Environmental Performance

These characteristics are not mutually exclusive from the whole system nor its parts. Proper material selection optimizes the building's overall efficiency and effectiveness in meeting its functional requirements.

Advances in material technology range from the contemporary to the exotic. Some new technologies already in use are carefully monitored for their long term performance, while others are being heavily researched for their applications in the near future.

Materials which provide dimensional stability, increased hardness and environmental resistance are most desired in industrialized building. In addition to these characteristics, materials and construction methods for lightweight building systems must have high strength to weight ratios, highly resistant to thermal flow, allow for easy erection and be economical.

Recent developments in glass fiber-reinforcement for concrete and plastics promises to revolutionize the building design and construction fields. Glass fiber-reinforcement allows for lighter building elements with significant increases in strength and dimensional stability. Additionally, the design strength and characteristics can be carefully controlled and designed into all building components. Current research is developing composite glass-reinforced primary building components such as column and beam members. While their long term evolution and design study continues, glass-reinforced plastics have proven to be a viable building material affording comprehensive environmental resistance coupled with excellent structural capabilities. Glass reinforced concrete provides for the possibility of very thin panel claddings with exceptional strength and lightness.

Glass reinforced plastics and concrete avail themselves to composite sandwich construction because of the following:

1. High strength to weight ratios. Extremely lightweight and versatile.
2. Precision control of dimensional tolerances during manufacture.
3. Precise control of design strengths and weights for specific component design.
4. Exceptional stability to all distructuve environmental forces without exception.

5. Maintenance free and durable.

6. Field repairable.

These characteristics make glass reinforced composite construction both viable and economical for long term serviceability and life.

Glass Reinforced Concrete (GRC)

Glass reinforced concrete is a mixture of portland cement, sand and glass fibers which combine to form a tough but light composite material. The great advantage of cement reinforced with glass fiber is the ability to produce much thinner and lighter elements in relation to traditional steel reinforcement. Glass fibers within the matrix, carry tensile forces eliminating the need for reinforcing steel. GRC provides the following characteristics:

* Weather resistance.
* Non-combustible.
* Low thermal movement.
* Resistance to environmental elements such as fungus, insects, ultra-violet, radiation and humidity, to name a few.
* High strength to weight ratio, allowing for thin, light sections.
* Early high impact resistance.
* Low thermal conductivity.

Because of the possibility of very thin sections, GRC can compete with lighter facing materials such as metals and plastics.

Summary of Physical Properties-GRC

Permeability	Impermeable to water and has low vapor permeability.
Temperature and Thermal Movement	Low thermal expansion.
Environmental Performance	Chemical and bacteria resistant.
Fire Performance	Rated non-combustible.
Thermal Conductivity	Negligible thermal insulation.

High Impact Durability

When used in composite sandwich construction, GRC provides a thin lightweight cladding material especially when lightweight cores such as expanded polystyrene beads or honeycomb construction is used. Because of the absence of aggregate and reinforcing steel, due to the use of glass reinforcement, GRC may be applied in layers as thin as one quarter of an inch.

Plastics

Plastics, because of their synthetic nature, offer a broad range of applications in construction from primary structural elements to secondary facing materials. Pure plastics frequently do not have the attributes needed or desired, and must be modified by stabilizers and glass reinforcements.

The exhibited properties of plastics vary considerably depending upon their chemical makeup. Plastics generally weigh considerably less than metals and most varieties of lightweight concrete. Because plastics afford low stiffness often limiting their use, glass fiber reinforcement provides the required strength and stiffness. On an equal weight basis, glass reinforced plastic is the strongest commercially available construction material. Such materials are known as glass reinforced polyesters (GRP).

Plastics, from the construction standpoint, offer advantages such as lightweight ease of fabrication, relatively low cost, durability, high strength and even, light transmission properties. Their potential and application can only be optimized when they are properly applied and their properties clearly understood.

The thermal conductivity of all plastics are low, consequently, glass reinforced plastics of sufficient thickness are good insulators and when used with glass fiber wool or foamed plastics as core materials in sandwich construction, extremely low U-values can result. The thermal expansion properties of GRP are comparable to that of aluminum.

Chemical resistance and light transmission properties of GRP vary according to the type and quality of resins used with the gel-coat exposed to the atmosphere. High or low qualities of either can be achieved. Abrasion and durability resistance depend upon the hardness of the surface. The environment in which the GRP panel is to perform has a major effect on the durability of GRP. The extent to which the physical and mechanical properties of the material declines with time due to the environment, has not been fully established. Temperature and humidity extremes coupled with intense solar radiation may cause rapid deterioration of plastics that are not suited to outdoor applications. Because of the valuable nature of plastic technology, it is impossible to identify any one limitation or use. The fact of the matter is that any suitable plastic composite can be formulated for any one particular end use. The tradeoffs, however, are usually high cost and questionable performance. Deterioration and uncertainty may be minimized by consideration of the following:

1. Knowing the specific conditions to be met by all the materials in the building.
2. Selection of a plastic material most suitable for the application.
3. Design to accommodate the properties of the plastic.
4. Design components for easy replacement.

Attributes of Glass Reinforced Plastics

Strength and Stiffness:

High strength to weight ratio depending on matrix direction of reinforcement. Filament-wound fibers afford exceptionally high strength, low weight.

Temperature and Time Effects:

Plastic properties of strength and stiffness vary with temperature changes. Laminates and reinforced plastics are least affected by temperature changes.

Toughness and Hardness:

Plastics are capable of extreme toughness and impact resistance, others can be soft and flexible.

Expansion and Contraction:

Relatively high coefficients of expansion can vary with the chemical composition and fiber reinforcement placement.

Thermal Conductivity:

Compared with metals, plastics are heat insulators. Thermal conductivity is low.

Light Transmission:

Plastics including GRP may by highly transparent or opaque. Solar transmission values may be as high as 90%.

Light Refraction:

In the vicinity of glass, coefficients of about 1.5 are possible.

Permeability:

Impervious to water vapor.

Environmental:

Corrosion resistant. Vermin, bacterial and insect resistant. Resistance to ultra-violet radiation can be obtained by the inclusion of stabilizers such as carbon black.

Fire Resistance:

Generally, plastics do not afford fire protection or resistance. Fillers, plasticizers and glass reinforcement increases both flammability resistance and cost.

Foam Plastics:

Very little structural use of foam plastics has been made so far. Their main use has been as core materials in sandwich panels. The main advantage of foam plastics such as polyurethane over other insulative materials are their excellent low thermal conductivity (0.02 $w/m^2/c^\circ$) coupled with good high temperature resistance and low vapor permeability.

The use of plastics in construction are so numerous that a complete attempt to detail all its end uses is impossible. A simple illustrative list attempts to overview their possible applications in building construction.

Primary Building Elements

Facing for Sandwich Panels	(GRP, PVC, PVF, PMMA) Reinforcrced plastics, high pressure laminates bonded to a variety of cores. Plastic films over metals, such as steel or aluminum for protection.

Cores for Sandwich Panels	Polystyrene, urethane, or PVC preformed and placed between rigid sheets. Honeycomb structure made up of paper impregnated with phenolformaldehyde.
Roofs	Reinforced plastics and or plastic coated fabrics in shell forms, sandwiches, etc. Opaque or translucent facings.
<u>Special Construction</u>	
Grids	Translucent plastic bonded to a metal grid (i.e. Kallwall).
Tension Fabrics	Nylon or glass fabrics coated with PVC. Transparent films.
<u>Secondary Building Elements</u>	
Roof Light Domes	Double domes minimize heat loss to condensation.
<u>Miscellaneous</u>	
Hardward	Provides corrosion-free maintenance free building elements.

Exterior Building Finishes

Walls, Bonded Films, and Sheets	Pigmented or transparent films or sheets bonded to various substrate, e.g. metal (GRP) or plywood. The advantages are integral color, resistance to corrosion and decay, and protection of substrate materials.

Mechanical and Electrical Building Elements

Water and Waste Piping, PVC	Corrosion resistance, lightness, toughness and ease of fabrication.
Tanks, Lavatories, Urnals, Showers, etc.	Gel-coated reinforced plastics and acrylics afford low weight, low thermal conductivity and resistance to bacteria and corrosion.

Room Component Manufacturing Concept

Room size boxes with sandwich walls, floor and ceilings consisting of filament-wound facings wound around a core of lightweight material such as foamed plastics. Ribs, posts and struts could be incorporated into the core itself if desired.

With such integration, lightweight boxes could be constructed to withstand impact loads of transport and installation.

Traditional Building Materials

The traditional building materials for lightweight construction remains wood, aluminum and steel, of which their attributes are well known. Stressed skin panels utilizing plywoods and wood frame members are by far the most economical construction available and affords high strength to weight ratios. However, wood is limited by its non-uniform and variable dimension tolerances and is not precise enough to achieve sophisticated uniform production units. Concrete is limited in its application because of its weight and typical large masses required.

Steel and aluminum affords themselves to lightweight construction and factory production because of their high strength to weight ratios and uniform, precise tolerances attainable. Because of their high strength and rigidity, they are most efficient in withstanding externally applied direct torsional loads.

Climate Control Strategies

Most buildings are designed for specific climate and geographical locations. Specific climate control strategies are typically incorporated into the design for year round comfort. The building concept addressed in this report must be capable of adapting to various climatic extremes. This ability to adjust to climatic extremes while maintaining human comfort is a critical attribute contributing toward the success of the system. To achieve this goal, the system must provide for a holistic design strategy which optimizes passive energy concepts to achieve a high degree of energy self-sufficiency.

This strategy is based on the need of self-reliance since energy resources cannot be assured for most military situations and in underdeveloped locations. Optimum system effectiveness is attainable only through completely integrated and adaptable climate control strategies.

This concept would accomplish the following objectives:

1. Economical: Provides for long term system economy by excluding expensive portable mechanical systems and fuel storage needs.
2. Adaptable: Holistic climatic control design provides one system for all possible climate situations eliminating a multiplicity of systems. One system is more economical than several systems.

Climate Design

The purpose of climatic design is to maintain or to minimize the energy dependence and cost in maintaining a comfortable thermal environment. This is accomplished through the integration of passive control strategies designed to naturally modify the interior microclimate. The building envelope in passive climate design is a mechanism through which heat exchange can occur

	CONDUCTION	CONVECTION	RADIATION	EVAPORATION
PROMOTE GAIN			promote solar gain	
RESIST LOSS	minimize conduction	minimize infiltration		
RESIST GAIN	minimize conduction	minimize infiltration	minimize solar gain	
PROMOTE LOSS	earth cooling	promote ventilation	radiation to sky	evaporative cooling

FIGURE 1: FUNDAMENTAL STRATEGIES OF CLIMATE CONTROL

between the interior and exterior environments. Fundamental control type options consist of admitting or excluding solar heat gain and or containing or rejecting heat energy present in the interior space. Most of the control type systems available are static and are found in the form of material masses, overhangs, insulations and orientations of glazings.

The selection of any one of these strategies will have a decided impact upon the design, construction and material selection of the building shell and interior organization. The application of these four heat flow control options along with the four mechanisms of heat transfer; convection, conduction, radiation and evaporative cooling combine to produce various climate control strategies. These various strategies are identified in figure one (1).

The strategies can be further classified into winter or summer climate design strategies. In a holistic design approach no one strategy should prevail to the extent that it impacts upon other strategies and their effectiveness. Rather, all systems should be integrated with one another to optimize each within a single functioning system. Compromises must be kept in line with the overall desired efficiency or performance.

The various climate control strategies are shown on the following table.

WINTER	SUMMER
* Restrict conductive heat flow.	* Promote natural ventilation.
* Restrict infiltration.	* Restrict solar heat gain.
* Promote solar gain.	* Promote evaporative cooling.
	* Promote radiant cooling.
	* Earth Cooling.

The appropiate use of any one of the above design strategies of climate control under any combination of ambient temperature and humidity conditions is determined by the local climate conditions and requirements for human comfort as determined by the bioclimatic chart comfort zones. Figure two (2) indicates with the use of the psychometric chart format, the parameters for human comfort as they relate to an appropriate climate control strategy. The limits of each strategy determines an effective zone in which each strategy can be employed. The building bioclimatic chart indicates that whenever ambient outdoor temperature and humidity conditions fall within the designated limits of a control strategy, the interior of a building designed to effectively execute that strategy will remain comfortable. Failure to address both heating and cooling needs as a function of local climatic conditions leads to the exclusion of one to the optimization of another. The result is in sacrifices in annual comfort and energy performance, and limits its operational geographic area.

BIOCLIMATIC NEEDS ANALYSIS
TOTAL HEATING 1-5
TOTAL COOLING 9-17
TOTAL COMFORT 7
DEHUMIDIFICATION 8-9, 15-16
HUMIDIFICATION 6A, 6B, (14)

STRATEGIES OF CLIMATE CONTROL
RESTRICT CONDUCTION 1-5, 9-11, 15-17
RESTRICT INFILTRATION 1-5, 16-17
PROMOTE SOLAR GAIN 1-5
RESTRICT SOLAR GAIN 6-17
PROMOTE VENTILATION 9-11
PROMOTE EVAPORATIVE CLG. 11, 13-14, (6B)
PROMOTE RADIANT COOLING 10-13
MECHANICAL COOLING 17
MECH CLG. & DEHUMID 15-16

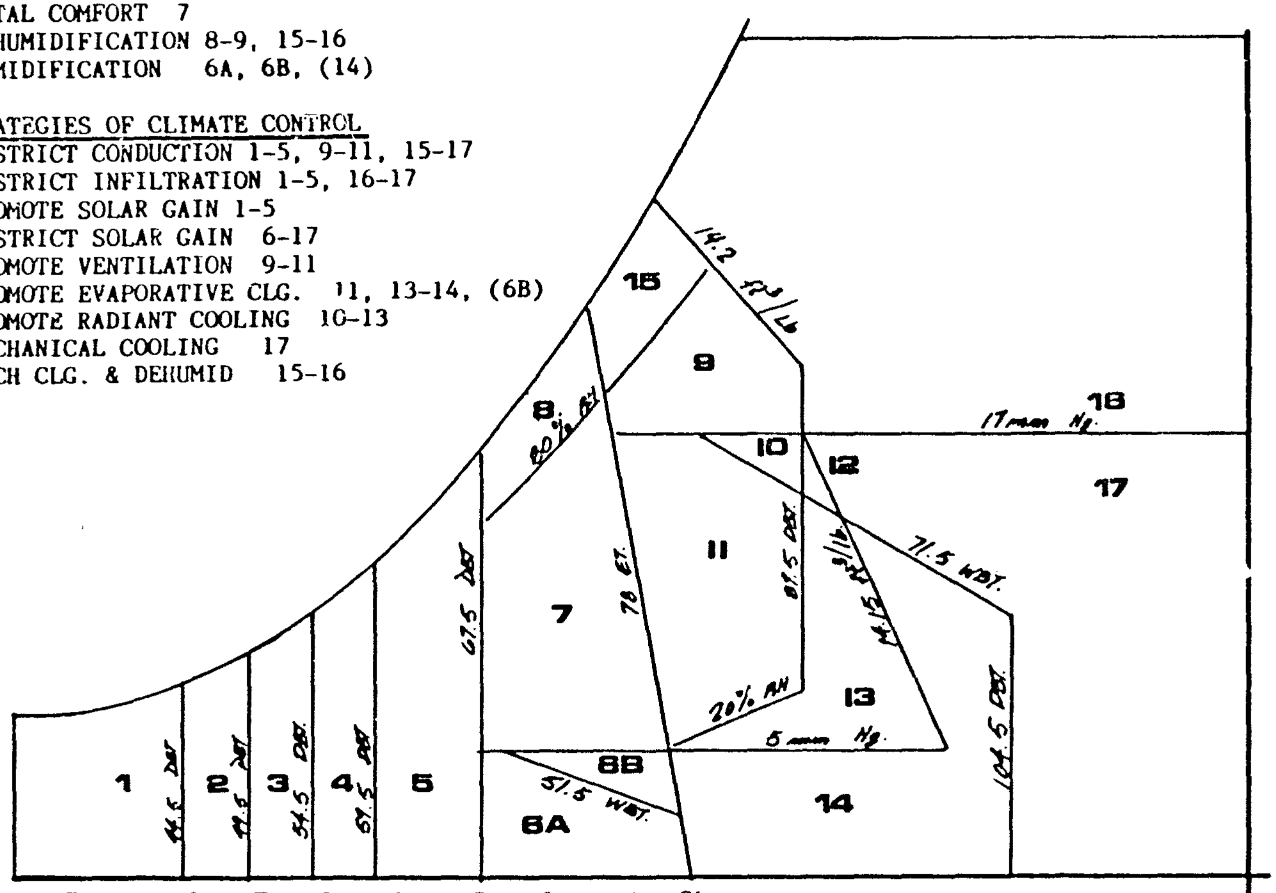

Figure 2: The Building Bioclimatic Chart

No one climate design strategy should be optimized over another where the geographical climate conditions vary with relative extremity. Generally, passive heating strategies are mote effective than passive cooling strategies. Passive cooling potential becomes more restrictive in its cooling capability due to usually increased absolute humidity, higher sensible heat loads and fewer, less effective cooling strategies available when most required. It is generally in hot dry and hot humid geographical areas in which passive cooling strategies must be optimized to approach the minimal ranges of the comfort zone. Generally speaking, the more cooling affect required, the less it is available.

Due to the relative limited capabilities of passive cooling strategies and a higher probability of greater military involvement within subtropical and desert geographical areas, passive cooling design strategies must be optimized.

Summer Climate Control Strategies

Passive winter control type strategies are relatively straightforward; restrict conductive heat flow, restrict infiltration and promote solar gain. Restriction of radiant heat flow transmission is primarily achieved through the use of restrictive insulations within the building envelope. Passive solar heating requires proper orientation of the building along an East-West axis, extencive use of glazing and materials with high storage capabilities. Usually these materials have high densities and weight. Design strategies to reduce heat loss through conduction usually require the structure to be decoupled from the earth or rely on extensive insulation to prevent heat loss from the interior. To minimize heat loss from possible infiltration and subsequent sensible heat loss, the structure's envelope must be tight.

The characteristics of a predominately designed passive heating system are as follows:

1. Building envelope well insulated.
2. System optimizes glazing for maximum solar infiltration.
3. Tnermal storage provided through heat capacitance materials.
4. Building joints minimized to reduce infiltration.
5. Building envelope minimized to reduce surface area.

Passive Cooling Strategies

Cooling strategies must not only address sensible heat gain but also absolute humidity control. The summer cooling strategies are: to promote natural ventilation; to restrict solar heat gain; to promote evaporative cooling and to promote radiant cooling.

Natural Ventilation

Two primary strategies are available for ventilating buildings. The suitability of each is related to the absolute humidity of the local climate. They are continual venting, (e.g. cross ventilation) and nighttime venting. Natural ventilation serves to accomplish the following:

1. Satisfies fresh air requirements.

2. Serves to increase the rate of evaporation and sensible heat loss from the body.

3. Cools the building by exchanging warm air for cooler, or treated outdoor air.

Natural ventilation applies to the movement of air due to the thermal forces (relative air densities) created by surrounding climate conditions such as wind or thermal forces.

Comfort in very humid overheated regions is attainable by natural means of constant air movement. The suitability and performance of ventilation is limited to the cooling sink potential of the dry bulb air temperature. In such regions, the diurnal temperature range is small due to the suppression of thermal radiation to the sky by a humid atmosphere resulting in nighttime temperatures not cool enough to counter balance the overheatness of the day. The greatest thermal advantage in design is obtained with the use of lightweight building shells that cool off quickly at night. Daytime temperature control is maintained by venting as effectively as possible to dissipate solar heat as well as to promote evaporative cooling of body heat. The promotion of natural ventilation is critical to optimize the control of humidity.

In dry arid regions, conditions are usually so dry and exceed comfort zone limits so greatly during the day that ventilation is undesirable from both the standpoint of bodily water balance and thermal comfort. The low humidity of the atmosphere allows temperatures to fall deeply at night so buildings constructed of high mass materials can maintain moderate temperatures throughout the daytime. The ventilation strategy for such regions is to vent the indoors at night and close the building during the day. Such diurnal ventilation is usually accomplished through the use of small penetrations and devices which precool the incoming air. Such mechanisms include evaporative screens, ventilation tunnels and towers.

Promote Radiant Loss

Three fundamental approaches to building shell design result from this strategy. They are:

1. Design for isolation from external conditions through thermal resistance.

2. Design for controlling timing of diurnal interaction with external conditions (thermal mass).

3. Design the building envelope as a ducting system to transport and distribute energy.

The potential of radiant loss is dependent upon the mean radiant temperature differentials between the external and interior environments. A minimal difference between the two will cause or induce the conductive heat flow from the warmer space to the cooler temperature. The use of such a strategy is reliant not only on the MRT differential, but requires direct coupling with the external environment which serves as a heat sink. This strategy precludes the use of insulations and wall treatments which create air spaces or decouples the space from the exterior.

The third approach utilizes the building envelope for promoting the transfer of heat energy throughout the structure. Double shell cavity walls and roofs can be utilized to complement natural ventilation around the shell, and restricts solar gain of the interior cavity through heat gain reduction and radiant cooling resulting from ventilation within the wall cavity.

Design Implications to Promote Radiant Loss

1. Use double wall and roof construction to promote natural ventilation, radiant heat loss and heat gain reduction.
2. Limit use of restrictive insulations in walls, roofs, and floors.
3. Use highly conductive materials.
4. Use direct earth contact to promote radiant heat loss.

Another approach to radiant cooling utilizes thermal mass to dampen the affects of daily temperature fluctuations. Such an approach is limited by the assumptions that : 1) the exterior shell is massive enough so that it dampens out daily temperature gains, thus maintaining a stable interior temperature close to the daily average; and 2) that the building is closed during the daytime minimizing solar gain and infiltration of heat.

A building structure designed to optimize such an approach must be thermally massive and have a highly reflective outer surface so solar gain is minimized. Such a strategy is optimized when incorporated with a nighttime ventilation strategy. This strategy relies upon the time lag capacity of materials with high thermal capacity. Essentially these materials, after storing daily heat gains, dissipate this heat slowly in the evening when the lower external temperatures allow for radiant cooling. This system precludes instantaneous transmission of daily heat gain.

Design Implications for Radiant Cooling/Thermal Mass

1. Use of high thermal and storage capacitances for walls and roof materials.
2. Design insulation with storage capacitances rather than exclusive restrictive insulation (i.e. polyurethane insulation or foamed urethane core, GRC)
3. Implies use with ventilation systems for optimum performance.

Solar Heat Gain Restriction

Possibly the most important single cooling strategy is to reduce the amount of solar heat gain to the building envelope. This can be accomplished by shading elements detached from the building shell or even by earth sheltering (partial or full earth contact). In either case, direct heat gain is restricted and the mean radiant temperature of either the air or surrounding earth determines the rate of conduction heat flow to or from the building envelope. One possible strategy is the use of double walled construction. Between the two enclosures is a passageway for natural ventilation to carry off heat buildup which minimizes the MRT.

Design Implications

1. Extensive use of shading materials and elements.
2. Restrict use of glazing.
3. Use lightweight building materials with high conductance capacity for rapid cool off.
4. Provide wall and roof components with decoupled interior and expernal facings with ventilatidn space in between to maintain stable ambient MRT surrounding the building envelope.
5. Provide for possible earth sheltering capability.

Promote Evaporative Cooling

The air cooling process through evaporative cooling can be used most effectively where the absolute and relative humidities are relatively low such as in dry arid regions. This strategy can be considered as a means of dissipating solar heat absorbed at the surface or as a means of extracting heat from the interior. The first strategy provides a method of reducing the amount of heat conducted through the shell into the interior while the second strategy relies on the outdoor air as a heat sink which evaporative processes exploit. For this latter method, the interior must be coupled with the evaporative surface through a highly conductive roof structure. The effectiveness of the evaporative cooling heat dissipation value depends on the following:

1. Solar reflectivity of the roof surface.
2. Ventilation of the underside of the roof.
3. Resistance of heat conductivity through insulation. (Roof mass reduces maximum intensity of heat gain but does little to reduce total daily heat load.)

Promote Conductive Cooling

The ground is the only sink in which a building can continuously lose heat by means of conduction. The rate of heat transfer is dictated by the mean radiant temperature differentials between the interior and ground surface temperature. This strategy requires the building envelope to be coupled directly to the earth and a ground temperature depression to induce heat flow.

Summary - Climate Control Strategies

The concept of providing a single building to provide a comfortable thermal environment throughout a wide range of climate extremes with minimal or no energy supply requires a holistic and comprehensive design strategy. Extensive use of passive climate control strategies provides the realization of such a goal. The high probability of conflict within the Middle East and tropical geographical areas require emphasis to be placed on summer cooling design strategies. Their number and effectiveness generally decreases as their needs increase, requiring full optimization of cooling strategies. Strategies to promote ventilation, solar heat gain reduction, evaporative cooling, maximizing earth cooling and radiant cooling potentials, all are required to be optimized and integrated into a holistic design strategy. Solar heating could be applied to domestic water heating and space heating requirements when needed. The use of high capacitance building materials and readily available materials such as sand and earth could help detain instantaneous heat gain and achieve a thermal flywheel affect. Radiant cooling could subsequently be employed in the evening hours, coupled with ventilation strategies to dissipate daily heat gains where absolute humidities permit. Because of the likelyhood of high humidity and temperatures to be encountered, ventilation must be maximized throughout the system's design and highly conductive materials utilized to optimize conduction and radiant cooling.

The following is a list of climate control strategies and variables which should be considered for application into a holistic building design.

Site Variables (Site Selection)

* Use neighboring land forms, structures or vegetation to aid or promote design strategies.
* Orientate building components to minimize solar gain, induce ventilation and promote ground temperature heat exchange.

Sun Shading

* Provide shading for walls and glazing exposed to the summer sun.

* Use heat reflective materials on floor and wall components.

* Provide exterior shading elements for roof system.

Thermal Envelope

* Select materials with high capacitance to control heat flow and preclude instantaneous heat gain.

* Minimize window and door openings.

* Use vestibule or exterior sun shielding at entry ways.

* Use conductive materials where possible to promote radiant cooling to ground and air heat sinks.

Natural Ventilation

* Use open air interior to promote air flow.

* Provide for the vertical flow, stack affect through air shafts to promote air flow and cross ventilation.

* Use double roof and wall construction for ventilation within the building shell.

* Provide optimum open wall area to promote natural ventilation. Use louvered walls where possible.

* Use wingwalls, overhangs, and louvers to direct and promote wind flow and venturi effects.

* Use roof monitors for stack effect ventilation.

Humidity Control

* Promote reduction of absolute humidity levels through the use of mass exchange coupled with ventilation systems.

Solar Walls and Storage

* Use passive solar collection techniques to store heat energy through either water storage or capacitance materials.
* Use passive solar system for domestic hot water exchange.

V. CURRENT STATUS OF PORTABLE MILITARY SHELTERS

Portable military shelters have generally been designed to provide short term occupancy for specialized and highly critical operations such as aircraft maintenance and emergency medical operations. These type of operations call for standardized and quality work environments to achieve optimum effeciency. Personnel shelters generally have seen less emphasis for development because of a wide range of commercially available pre-engineered systems and a questionable need in replacement of time proven tent sheltering systems.

The function of a portable sheltering system is unique and unquestionably meets the current needs of the rapid deployment force concept. Such systems makes military personnel immediately available for their primary mission; provides a recoverable and reusable system whereby preventing loss by friendly forces and gain by unfriendly forces, and they can provide a quality habitable and standardized living environment for short or long term missions. Portable sheltering systems, because of their reuse capability, can provide an economical and feasible alternative to typical pre-engineered building systems which have limited capabilities.

While inherently economical in its concept, the development of hybrid portable military shelters have been severely limited by the same criteria used for their development. Emphasis on maximum economy has severely limited the flexibility and potential of mobile shelters. Design and construction are governed by ISO container and transport requirements while typical service life is programmed for no more than five years of continual use, or ten years storage life. Tne result of such constrictive parameters for development has evolved a family of standardized expandable and non-expandable transport containers modified to adequately support occupancy. However, they are severely limited in their flexibility and use whereby pre-empting their further development and continued interest. Contributing to their demise is their ability to respond to a variety of user needs, climates, and various site topographies. Extensive support equipment is also required for their transport, erection and sustained thermal comfort for the occupants.

Off the shelf, commercially available portable building systems generally have the same limitations and deficiencies which prohibit their use as a highly portable and flexible sheltering system. Most commercial systems do not provide for phased construction. They are usually fixed volume modules having limited functional and complexing ability. Such systems are highly dependent on mechanical cooling and heating systems required to maintain thermal comfort. Also due to their volume and shear weight, specialized transport equipment is necessary for handling and erection.

Other off the shelf, commercially available systems are generally more of the pre-engineered building type. Extensive site construction effort and time is required. In retrospect, both type systems have severe limitations which preclude their effectiveness as truly portable shelter systems. The implication of the current status of shelters indicates a need to formulate a new set of programmed criteria moving away from stringent economics towards optimum flexibility and adaptability. Failure to develop new development program criteria shall result in continual development of limited flexibility systems limiting the logistical and strategic capabilities of the Armed Forces.

VI. THE NEED

Vietnam marked a turning point of construction requirements needed by the military for a number of reasons. This conflict spanned a period of over ten years in which the United States committed over 11 billion dollars to building programs. While this figure includes non-recoverable items such as port facilities, roads, bridges and airfields, many other facilities such as hospitals, housing facilities and administrative facilities were constructed. The legacy of Vietnam will be in part remembered for an enormous construction effort which has in turn benefited the enemy after our withdraw and eventual defeat of South Vietnam. The lesson learned is that not all conflicts are finite, short term involvements with predictable positive outcomes. The use of permanently constructed facilities should be questioned when conflicts such as Vietnam arise in the future.

Almost a decade and a half later, American Marines in the Middle East were tasked as peacemakers in Lebanon for an unspecified duration. The occupational forces had to rely upon the existing urban facilities for support and housing of its troops. The concentration of personnel and reliance upon a local urban facility resulted in tragedy. Soon afterwards a rapid phased withdraw again was underway under strikingly similar circumstances as in Vietnam.

Both situations have similar characteristics even though the situations and locations are different. Contemporary military logistics and tactics have evolved the concept of "Rapid Deployment Forces." The term itself signifies a new strategy for conflict involvement. These situations all underscore the need for a portable shelter system of increased sophistication.

Attributes

One of the primary objectives and needs of such a system is a simple erectable building system providing a cost effective and high quality standardized living environment. The system must be able to provide a comfortable environment throughout a wide range of climate extremes over short or long term occupational basis. The need to provide a wide range of functions in a variety of sizes requires the system to be highly flexible. To achieve these primary requirements and objectives the necessary attributes of the system are as follows:

1. Easily erectable components using only standard tools and materials.
2. Flexible; provides for expansion and a variety of arrangements.
3. Climate adaptive; provides a comfortable thermal environment throughout a wide range of climate extremes.
4. Transportable.
5. Reusable/portable.
6. Site adaptable.
7. Durable.

8. Minimal maintenance required.
9. Fragmentation hardened.
10. Cost effective.
11. Lightweight.

These attributes establish the essential program guidelines which must be satisfied and integrated into a successful systems design. Failure to integrate any one of these attributes will possibly render the system ineffective. The design goal shall be to apportion all these elements equally to achieve a fully integrative system.

In order to insure a comprehensive and systematic approach to the design process, an understanding of basic principles and concepts of systems building is required. A rationalized building approach attempts to standardize the building process. Based on a modular concept, this area of study provides a benchmark from which to organize the design process and provides rationale into the building system with regularity and interchangeability.

SECTION 2

PROGRAMMING

Executive Summary - Programming

This section identifies the major attributes and criteria based on the user needs and objectives of the system. After these attributes were identified specifications as to their limitations and performance were identified based upon previous study and already established criteria by the Department of Defense. Selection of the system's concept, construction, systems and material selections were made based on their potential to satisfactorily meet the projected criteria.

No commercially available system is available to meet the program's functional specification. Design criteria requires the development of a prototypical design with the utmost flexibility of design, assemblage, transport and thermal performance.

The basic concept relies on a modular aluminum skeletal frame system designed to be stored and shipped within standard (ISO) containers. Secondary modular panels consisting of composite construction are to be inlaid between structural elements to increase rigidity and provide enclosure. System is governed by the following attributes.

* Department of Defense design guidelines
* Site adapability
* Simple erection
* Transportable
* Flexibility

* Repair and maintenance
* Optimum thermal comfort performance in varying climate extremes
* Energy self-sufficiency through passive climate control strategies
* Economical use of materials and systems

These criteria establishes a general systems plan for the detailed design to follow. Detailed design and integration of geometry and system to be performed in (692) Professional Study program.

Design Guidelines for a Portable Modular Component Building System

System Objectives and Goals

* To make military forces immediately available for their mission by providing a portable, reusable building system minimizing set up and strikedown times.

* To prevent loss of real property, supplies and materials to the enemy in the event of a rapid withdraw.

* To reduce the amount of construction effort and damaged, lost, stolen and misdirected material.

* To develop a single inter-service building system readily available and responsive to a variety of functional requirements, needs and uses.

* To develop a system capable of maintaining a comfortable thermal environment throughout a wide range of climate extremes.

* To develop an energy efficient and self-sufficient building system to reduce reliance upon local utilities and continuous resupply of fuels.

System Requirements

Key attributes were identified to meet the concept's objectives and goals. These elements are as follows:

* Meet Department of Defense requirements for relocatable shelters.

* Site adaptable.

* Provides for easy erection and disassembly.

* Relocatable, lightweight, transportable system.

* Flexibility.

* Provides for easy repair and maintenance.

* Provides for optimum thermal comfort in climate extremes of temperature and humidity.

* Fragmentation hardened.

* Economical.

* Habitable.

* Energy efficient.

Requirements - Definitions

Attribute	Definition
Department of Defense Guidelines	* Meets MIL-STD-907A of 31 March 1983; "Military Standard Engineering and Design Criteria for Shelters, Expandable and Non-expandable."
Site Adaptable	* Minimum site preparation required. * No special site foundation requirements needed.
Erection Simplicity	* The speed, ease, handling and erection by untrained personnel without special equipment and/or tools. Sections and assembly are recognizable and understood.
Lightweight and Transportable	* System is capable of varying means of transport including air, sea, land and field transport. System capable of field handling by personnel without special equipment.
Flexibility	* Capable of varying interior room volumes for various user requirements. * Capable of various groupings and arrangements.

Attribute	Definition
Repair and Maintenance	* Components, once in place, can be retrieved and replaced without affecting system's integrity of design.
Thermal Performance	* System can maintain thermal comfort in climate extremes of temperature and humidity.
Fragmentation Hardened	* Building envelope provides limited impact resistance to small arms fire and airborn fragments.
Economical	* Economical use of materials and systems to achieve project goals and long term usefulness. High initial cost would be offset by long systems life cycle and energy savings.
Habitable	* Physical, thermal, and psychological comfort are optimized in the building concept. System does not promote austere military environment.
Energy Efficient	* Optimizes passive climate design principles and daylighting to minimize energy dependency and mechanical systems. System is self-sufficient.

DESIGN SPECIFICATIONS

Attribute	Reference Publications
Meets DOD requirements for portable shelters.	* MIL-STD-907A (see Appendix A) * MIL-A-8421 (General Spec. for Air Transport) Appendix B * NEC (18) * ANSI A119.1 * MIL-STD-1472 (Human Engineering Design Criteria)

Site Adaptable

Attribute	Design Specifications Criteria
Adjustable and Self Leveling	* Adapts to level sites without need of separate support systems or prepared foundation. * Adapts to sloping sites no greater than 10%.
Versatile Support System	* Adaptable to a broad range of soil types including permafrost. * System can allow for earth contact or elevated support.
Load Distribution	* Distributes loads uniformly to support bases. * Offers potential of easy adaptation between principle design modules and load transfer.
Retrievable	* Foundation support system integrated within main structure. * Support system applicable to a broad range of soil types.

Site Adaptable

System Selection

System Support

* Point load concentration using adjustable pedestal bases with leveling indicators.

* Designed for manual or pneumatic adjustment.

* Base pads to accommodate varying soil types.

* Support system integrated within the main support module to properly distribute load transfer.

* Positioned on regular grid pattern.

* Supports can be raised to allow for direct ground contact with building envelope.

Simple Erection Capability

Attribute	Design Specification
Simplicity	* No experience or training required for assembly. * No special tools required. * No special equipment required.
Erection Time	* Minimum erection rate: 2 man-hours per $150ft^2$.
Effectiveness	* Erection system is complete, contained and integrated among all components.
Simple/Integration	* Components are keyed or coded for proper alignment into assembly. * Components are readily recognized. * Connections are complete, ready to join without secondary or separate joining elements.
Field Handling	* Components are capable of easy field handling and emplacement. * A minimum of four to six individuals required to maneuver the largest of components.

Erection Simplicity

System Selection

Design Concept

* Modular aluminum skeletal frame system serving as the primary structure and organizational system with secondary cladding panels serving as wall, roof and floor elements.

* Secondary elements reinforce structure as shear walls adding rigidity and serve as the structure's finish.

Subattributes

* Frame and panels organized on a regular grid pattern.

* Sub-systems and utilities organized within primary structural grid for coordination.

* Secondary building panels and elements contained wihtin primary skeletal frame for shipping, storage and rapid deployment and erection.

* Joints utilize a compression spline adjusted with ratchet. Spline incorporated within panels (wall panels).

Transportation Mobility

Attribute	Design Specification
Logistics	* Capable of air transport by fixed wing aircraft: C-141, C-130, C-5A * Capable of air transport by helicopter: UH1, CH 53, CH 47, Skycrane * Capable of rail transport. * Capable of sea transport by (150) container. * Capable of road transport. Maximum road transport width shall not exceed 12'0".
Field Handling	* System requires no special handling equipment in field. Can be manually maneuvered and assembled.
Containment	* Components capable of containerization within standard (150) containers (8 X 8 X 20), for shipping and storage.

Transportation Mobility Continued

Effectiveness	* System optimizes shipping economy by maximum utilization of interior volume. * System's secondary building elements are self-contained within structural framework and are organized for rapid assemblage.
Durable	* System capable of resisting normal impact loads of transport and erection.

Transportable

Design Concept:

* Regular Modules Designed to be stored and shipped within standard (ISO) Containers: 8 X 8 X 20.

* Modules to have individual wheeled capacity.

Flexibility

Attribute	Design Specification
Versatility	* System components provides for combinations in various groupings and sizes. * Various interior arrangements and room volumes can be achieved. * Utilities and mechanical distribution systems based on uniform grid pattern for coordination and expansion between modules.
Efficiency	* Provides for high expansion ratio to minimize total number of modules. Expansion ratio is defined as: $ER = \frac{\text{Shipping SF Area}}{\text{Operational SF Area}}$

Flexibility

Design Concept Selection

* Expandable modular skeletal frame system utilizing lightweight aluminum tubular frame and truss. Expansion capability in all horizontal and vertical directions.

* Interior demountable partitions to be located on regular modular grid pattern along with utility distribution and mechanical systems.

* Utility distribution within structural frame system.

Repair and Maintenance

Attributes	Design Specification
Interchangeable	* Components are based upon uniform modular design, tolerances and dimensions. * Components once in place can be retrieved and replaced without loss of system integrity.
Durable	* Facing materials exhibit a high degree of resistance to impact and abuse. * Materials are resistant to: Corrosion Moisture penetration and damage Vermin and insects Fungus and bacteria Chemicals * Exterior materials are restrictive to environmental elements (wind, ultra-violet exposure, etc.).

Repair and Maintenance Continued

Attribute	Design Specification
Durable	* Components require no maintenance of surface finishes.

Component and Material Selections

Exterior Wall Panels: Composite sandwich construction consisting of the following:

Exterior Cladding	* Glass reinforced concrete (GRC) ½" thick, embossed with a thin film of urethane for impact durability.
Core (options)	* Honeycomb core composed of aluminum or polystyrene insulation (Klegecell) * Honeycomb core with aluminum grid for filling with site materials such as sand or tampered earth.
Interior Facing	* Glass fiber reinforced polyester shell (GRP)

Interior Wall Panels

Facing	* Glass fiber reinforced polyester
Core	* Aluminum honeycomb * Louvers located in panels to maximize and assist natural cross ventilation.

Floor System	Modular floor system consisting of an aluminum grid and removable floor panels. The floor panels can accept a wide range of finishes. Joints are sealed with neoprene gaskets. The floor system is a raised floor with an 18" maximum clear space for service distribution.
Floor Panels	Fiberglass reinforced waffles organized on a regular 32 in. grid. Fiberglass grating panels also available for use.
Roof System	Double roof envelope. Exterior roof system capable of adjusting to various slopes. Roof system serves to retard solar heat gain and assists natural ventilation.
Roof Panels	Exterior Shell Fiberglass reinforced panels (lascolite) solar white. Interior Shell Aluminum sandwich (ribbed construction) with aluminum honeycomb core (white). Clearstories Translucent fiberglass with sandwiched insulation (Kalwall sunwall). Windows Lexan polycarbonate sheets (¼").

Thermal Performance

Attribute	Design Specifications
Effectiveness	* System actively modifies interior thermal environment to control temperature, humidity and ventilation ratio. * Low temperature performance designed to meet thermal comfort at -35°F outdoor temperature. * High temperature performance designed to meet thermal comfort at 135°F ambient air temperature. * System actively promotes natural ventilation for thermal comfort and air change. * System provides for humidity control to be maintained within the comfort zone. * System designed for user control of heating, cooling and ventilating systems. * Overall thermal transfer value .35BTU/HR. 1FT².

Thermal Performance Continued

Attribute	Design Specification
Simple	* Environmental system controls are simple to use and maintain. * System affords simple and easy component modifications to adapt to different climatic conditions.
Versatility	* Primary environmental systems designed for passive climate control. * Backup mechanical systems designed to assist passive controls and not as primary systems function.

Energy Efficient

Attribute	Design Specification
Self-sufficient	* Minimal reliance on fuels or utilities.
Passive Design Reliance	* Optimum use of passive thermal control strategies.
Primary Climate Control Strategy	* Predominate summer cooling strategy: Promote ventilation Minimize solar gain Promote radiant cooling Potential for earth cooling Promotes evaporative cooling
Secondary Climate Control Strategy	* Secondary winter heating strategy: Minimize conductive heat flow Promote solar gain and storage Minimize infiltration External air flow
Illumination	* Optimizes daylighting for even light distribution.

System Selection

Passive Design Strategy

Ventilation

* Use open plan interior to promote air flow.
* Provide vertical air shafts to promote air flow.
* Use double roof and wall construction for heat gain reduction and continued venting of the interior building shell.
* Use wingwalls, overhangs and louvers to direct summer wind flow into the interior.
* Use louvered walls for maximum ventilation.
* Use sloped roofs to create roof monitors for stack effect ventilation.

Solar Heat Gain Reduction

* Provide shading for walls and roofs exposed to the summer sun.
* Use heat reflective materials on exterior wall and roof surfaces.
* Use high capacitance materials to control heat flow through building envelope.

Promote Radiant Cooling/Thermal Mass

* Cavity walls to be filled at site with sand or soil for thermal flywheel affect.

* Use conductive building materials.

Evaporative Cooling

* (optional) Roof pond system for evaporative cooling potential.

Earth Sheltering Potential

* Utilize direct earth contact to maximize ground temperature heat exchange.

* Provide option for recessing system below grade and/or earth berming for protection and ground temperature heat exchange.

Selective Promotion of Solar Gain

* Use roof collectors to store solar heat and domestic hot water heating

Mechanical Backup System

* Heat pump system.

Fragmentation Hardened

Attribute	Design Specification
Impact Resistant	* Exterior cladding capable of withstanding small arms fire and airborne fragments.
	* System capable of an earth protective covering (e.g. earth berming) for additional protection.

System Selection

* Exterior wall panels have hollow cores in which sand or tampered earth can be placed. Cores are based on a standard grid and are removable to fill individual cells.
* Exterior shell capable of resisting earth loads up to 6 feet of bermed height.

Habitability

Attribute	Design Specification
Illumination	* Provides visual access to out-doors.
Control	* User control over environmental, thermal and lighting systems provided.
Spatial	* Provides for segrigation of interior spaces for individual space functions.
Acoustical	* Interior finish materials provide high acoustical impedance.
Psychological	* Interior finishes contribute positively to the psychological comfort by providing colors, textures and spacial variations. * System promotes feeling of durability, permanence and security of construction.

Executive Summary

Material and Systems Selection

Foundation Design

* For flexibility and ease of handling the modules the structural frame must be capable of being supported at points rather than requiring continuous support.

* The modules must be capable of direct ground contact to optimize the earth's heat sink potential for radiant cooling.

* Supports are self adjusting and leveling either manually or pneumatically. Extensions of at least 48" - 60" required for site slope differentials.

Design Concept

* Expandable modular skeletal structural frame serving as the primary structure and organizing element, constructed of aluminum box members. Basic members are columns and beams.

* Secondary modular wall panels serve as shear walls and fit within structural frame. Structural frame also serves as utility destribution network.

* Connections: all structural connections are rigid and uniform providing for vertical and horizontal attachment of columns and beams.

Design Concept Continued

* Dimensions, geometry and design subject of 692 Professional Study.

* Utilities and mechanical distribution coordinated and integrated on a regular grid module. Structural and utility distribution systems utilize the same module and grid system.

Floor System

* Space for mechanical distribution and equipment is provided within floor assembly. Regular network based on grid pattern organizes distribution and coordination.

* Floor assembly is a modular pedistal supported removable panel system. Modules are a nominal 2" thick and constructed of a fiberglass (GRP) waffle with a core of aluminum honeycomb. Panels for air distribution are constructed of a fiberglass (GRP) grating.

* Floor planning module 32" (8m) o.c.

Ceiling System

* Suspended type ceiling on modular grid. Textual-acrylic coating over aluminum panels.

* Provides for modular arrangements of lighting, ventilation and air distribution.

* Suspended ceiling promotes natural ventilation and does

Ceiling System Continued

not create dead air spaces.

Exterior Wall Panels

* Wall panels are of composite sandwich construction.

Exterior skin material: Glass reinforced concrete $\frac{1}{4}$" thick with a film of urethane for color (white) and impact durability.

* Core material: Klegecell, a structural cellular P.V.C. material (optional core consists of aluminum honeycomb).

* Interior facing: glass reinforced polyester (GRP).

Interion Wall Panels

* Double faced with (GRP) with aluminum honeycomb core (3") nominal thickness.

Special Panels

* Kallwall (skywall panels) for clearstory daylighting.
* Sunshading provided by reflective fabric material.

Roof System

* Roof system is a double roof with movable exterior roof panels to promote natural ventilation and heat gain reduction.

Roof System Continued

* Exterior shell: fiberglass reinforced polyester, lascolite panels, solar white with core material of Klegecell.

* Interior shell: aluminum sandwich, ribbed construction modular panels with aluminum honeycomb core.

Nature of Expected Results

The 692 Professional Study program shall attempt to demonstrate the feasibility of the program goals and objectives. The results of the professional study will document the following:

1. The design and development of a portable modular component building system meeting the program specifications and requirements.
2. Evaluation of the system's geometry through a series of physical modeling studies relative to the specific geographic climate and site locations.
3. To evaluate whether or not the development goals were met, well defined and feasible.
4. To further the future development and research of this concept, within the Department of Defense.

BUILDING PROGRAM 1

The following scenarios depict specific sites, functional requirements and various climates in which the building system is to respond. They shall be the subject of the 692 Professional Study program.

Building Program I

This program will be designed to evaluate the modular component system for its utility and flexibility in meeting the requirements of a fleet hospital facility.The Fleet Hospital program initiated by the Navy in May 1979, was intended to develope 250, 500, 750 and 1000 bed self-contained, air transportable,relocatable,quickly erectable modular hospital units. The ultimate goal of this program is to acquire a 12,000 bed hospital system.

Project Statement 1.

A site in Saudi Arabia has been selected for the 30 bed United States fleet hospital construction exercise in response to increased air and sea military operations by Iran. An influx of merchant marine casualities has created a need for such a facility with future expansion capabilities for anticipated military conflict between Iran and Saudi Arabia. The request for the facility has been made by the Saudi government which has also provided for the site's location.

The site, while located within the territory of a non-aligned ally is not secure from terrorists attacks. Iran has committed itself to eliminating American presence within the area. Saudi Arabia, while requesting the facility, cannot publicly promote the United States presence for fear of internal retrobution from its own people. The United States is committed to honor the request, acknowledging the risks and special requirements.

The Secretary of the Navy is committed for a long term presence to help stabilize the area and protect American interest. However, military forces must be able to evacuate the site immediately upon notification from the Saudi government if the political winds dictate. The hospital facility will be relocated to the island of Bahrayn in such an event.

Site Description

I. Soils and sub-surface conditions.

1. Wet sand, well-graded sands, or gravelly sands. Good foundation material where dry only.

II. Climate - See attached LCD data for temperatures (averages and extremes), precipitation, and sun angles.

III. Energy use and conservation.

Due to the possibility of terrorist activities and remoteness of the site, the facility must be energy efficient and independent. Electrical utilities are locally available. No other utilities are available.

IV. Erection Logistics.

System shall be sea-air transported to land where ground forces will transport to the site with vehicles. The majority of the modules will be air lifted to the site directly. The site is in close proximity to an airfield.

Base Facility Requirements

Space requirements indicated are approximate net square feet.

I. Medical requirements

a.	Casuality receiving area	500 sq.ft.
b.	Operating room prep/hold	500 sq.ft.
c.	Surgical work space	250 sq.ft.
d.	Operating rooms (3) @ 300sq.ft.ea.	900 sq.ft.
e.	Recovery room	500 sq.ft.
f.	Intensive care unit	1000 sq.ft.
g.	Linen/storage	800 sq.ft
h.	Pharmacy/blood storage	600 sq.ft.
i.	Patient rooms (30 beds)	2880 sq.ft.

II. Administration

a.	Records	375 sq.ft.
b.	Office space	500 sq.ft.
c.	Multi-purpose	500 sq.ft.

III. Sanitation Facilities

a.	Provide for in each patient room: 1 lavatory 1 watercloset	25 sq.ft.
b.	Other facilities (staff) 6 lavatories 6 waterclosets 4 urinals	500 sq.ft.

Base Facility Requirements Continued

IV. Food preparation facility and supporting facilities to be indicated but are not part of this detailed evaluation. Supporting facilities utilize typical module component systems.

Local Climatological Data

Annual Summary With Comparative Data

1982

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

YUMA, ARIZONA

Narrative Climatological Summary

[illegible] climate of Yuma is definitely a desert product. During the winters, home-heating is necessary from [illegible] October until the 10th of April; but work or play can be conducted comfortably out-of-doors from about [illegible] a.m. to 5 p.m. during the winter, which is a period of mostly clear skies and abundant sunshine. Fr[illegible] [illegible] not uncommon in the nearby valleys and must be expected occasionally on higher lands.

[illegible] the period from November 1 to April 1 there are, on the average, 16 daylight hours with rain, a little [illegible] than three a month. There are places in the world where more rain has fallen in a single year than [illegible] fallen at Yuma during the past [illegible] years.

[illegible] every day, but comes nearer doing so at Yuma than any other place in the [illegible] which we have records. Even in December and January the lower Colorado River Valley [illegible] averages [illegible] than eight hours of sunshine a day.

[illegible] summers in this country are long and hot. Afternoon temperatures reach 100°, on the average, from June [illegible] to September [illegible], and 105° from July 2 to August 14. An extreme of 120° has been reached four times [illegible] [illegible] of 123° was registered on September 1, 1950.

[illegible] in moisture-laden air from the Gulf of [illegible] [illegible] from mid-July to mid-September is higher than [illegible] [illegible] results from the relative nearness to the Gulf of Lower California. [illegible] [illegible] effective for cooling purposes during all the months except July, August, and September, [illegible] the wet bulb temperatures are frequently between 75° and 80° — a condition that makes the [illegible] [illegible] cooler somewhat ineffective.

[illegible] RECORDED AT YUMA ARE INDICATED BELOW.

[illegible] days with:

[illegible] temperature [illegible] or higher, 133 in 1973.
[illegible] temperature 100° or higher, 101 in 1937.
[illegible] temperature [illegible] or higher, [illegible] in 1955.
[illegible] temperature [illegible] or lower, [illegible] in 1913.
[illegible] temperature [illegible] or higher, [illegible] in 1959.
[illegible] inch or more, 7 in [illegible].
[illegible] rainfall as great as 0.01 inch, from December 29, [illegible] to [illegible] 15, [illegible], 131 days.

[illegible]

[illegible] mean temperature [illegible] 101.5° [illegible]

[illegible] July [illegible] with [illegible] temperature of [illegible]. The [illegible] was [illegible], and the minimum [illegible] averaged [illegible].

[illegible] year [illegible] 1958 [illegible] temperature of [illegible]. [illegible] average [illegible] 61.9°

Coldest day was January [illegible], 1913, with a mean temperature of [illegible]. The maximum temperature [illegible] was 36° and the minimum temperature was [illegible].

Coldest month was January 19[illegible] with an average of 44.9°. The maximum temperature averaged [illegible], and the minimum [illegible].

Coldest year was 190[illegible] with an average of [illegible]. The average maximum was [illegible] and the minimum 55.2°.

Highest temperature ever recorded at Yuma was 123° on September 1, 1950.

Lowest temperature ever recorded [illegible] on January 24, 1937, [illegible], 1911, and January 20, 1883.

Wettest year on record, [illegible], [illegible] of rainfall.

Driest year on record, 19[illegible], with [illegible] rainfall.

[illegible] new entries [illegible] the records [illegible] December 19[illegible] [illegible] and December [illegible].

noaa [illegible] NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION [illegible] ENVIRONMENTAL DATA AND INFORMATION SERVICE [illegible] NATIONAL CLIMATIC [illegible] ASHEVILLE, N.C.

Meteorological Data For The Current Year

Month	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating degree days	Cooling degree days	Water equivalent Total	Greatest in 24 hrs	Date	Snow, Ice pellets Total	Greatest in 24 hrs
JAN	69.2	44.5	[illegible]	79	26	35	[illegible]	26	[illegible]	0.[illegible]	0.17	10-11	0.0	0.0
FEB	75.6	50.7	63.2	89	21	39	[illegible]	[illegible]	[illegible]	0.14	0.12	24	0.0	[illegible]
MAR	76.5	51.9	[illegible]	[illegible]	10	44	[illegible]	[illegible]	[illegible]	1.16	0.44	14	[illegible]	0.0
APR	47.2	58.6	[illegible]	[illegible]	28	46	[illegible]	5	244	[illegible]	0.70		0.0	0.0
MAY	94.1	63.7	78.9	103	25	53	12	0	[illegible]	T	T	3	0.0	0.0
JUN	[illegible]	69.5	84.9	110	27	63	[illegible]	0	602	0.00	0.00		0.0	0.0
JUL	[illegible]	[illegible]	[illegible]	114	14	[illegible]	[illegible]	[illegible]	[illegible]	0.23	0.23	25	0.0	0.0
AUG	[illegible]	[illegible]	[illegible]	114	20	75	[illegible]	[illegible]	476	0.93	0.63	24-25	0.0	0.0
SEP	[illegible]	73.6	86.2	115	2	[illegible]	[illegible]	[illegible]	[illegible]	0.16	0.13	7-8	0.0	0.0
OCT	[illegible]	[illegible]	[illegible]	97	23	51	3	[illegible]	[illegible]	T	T	26	0.0	0.0
NOV	74.5	51.2	62.9	94	5	41	11	[illegible]	[illegible]	0.46	0.23	17	0.0	0.0
DEC	66.2	44.9	55.6	75	20	37	[illegible]	[illegible]	0	2.09	1.87	8-9	0.0	0.0
YEAR	87.0	60.6	73.9	115	SEP 2	[illegible]	JAN [illegible]	[illegible]	4154	5.46	1.87	DEC 8-9	0.0	0.0

Normals, Means, And Extremes

Month	Normal Daily maximum	Normal Daily minimum	Normal Monthly	Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F Heating	Cooling	Water equivalent Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets Maximum monthly	Year	Maximum in 24 hrs	Year
(a)				32		32					32		32		32		32		32	
J	67.4	43.3	55.4	88	1971	24	1971	306	4	0.36	2.12	1979	T	1975	1.29	1979	0.0		0.0	
F	72.6	[illegible]	59.4	92	1931	28	1956	192	[illegible]	0.27	1.82	1958	0.00	1974	1.34	1958	0.0		0.0	
M	77.5	50.2	63.7	98	1966	32	1951	97	[illegible]	0.21	1.16	1982	0.00	1972	0.62	1973	0.0		0.0	
A	85.6	55.7	71.2	106	1930	41	1977	24	[illegible]	0.11	1.20	1965	0.00	1982	1.08	1965	0.0		0.0	
M	93.4	[illegible]	78.7	113	1974	46	1967	0	412	0.01	0.37	1965	0.00	1975	0.37	1965	0.0		0.0	
J	100.8	70.8	85.8	115	1979	54	1955	0	666	0.00	0.27	1972	0.00	1982	0.26	1972	0.0		0.0	
J	106.0	81.4	93.7	119	1958	63	1956	0	887	0.18	1.07	1958	0.00	1980	1.06	1958	0.0		0.0	
A	104.4	81.2	92.8	120	1981	63	1968	0	849	0.44	2.96	1977	0.00	1976	2.72	1977	0.0		0.0	
S	103.3	73.9	87.1	115	1982	53	1965	0	663	0.22	2.47	1963	0.00	1980	2.42	1963	0.0		0.0	
O	89.8	62.0	75.9	112	1980	35	1971	5	161	0.27	2.68	1957	0.00	1981	2.20	1972	0.0		0.0	
N	76.5	50.5	63.5	98	1962	30	1959	108	56	0.22	1.66	1969	0.00	1980	1.42	1969	0.0		0.0	
D	68.2	[illegible]	56.3	86	1958	27	1968	276	12	0.34	2.09	1982	0.00	1981	1.47	1992	T	1967	T	1967
YR	86.9	60.4	73.7	120	AUG 1981	24	JAN 1971	1010	4244	2.67	2.96	AUG 1977	0.00	JUN 1982	2.72	AUG 1977	T	DEC 1967	T	DEC 1967

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 123 in September 1950; lowest temperature [illegible] in January 1937 [illegible] maximum monthly precipitation 6.25 in August 1961; maximum precipitation in 24 hours 4.?? in August 1961.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for the 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Heating Degree Days

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Cooling Degree Days

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Snowfall

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

BUILDING PROGRAM 2

Project Statement 2.

A site near an existing airport has been selected for the base camp in support of naval sea and air forces. The surrounding air field perimeter remains under continual harassing fire and because of the surrounding dense jungle, terrain and political restrictions limits for counterstrikes to secure the area have been made. The base is to support the occupational forces in maintaining airfield operations for an unspecified duration until a political settlement can be made. No utilities are available to the site.

Because of the political uncertainties and shifting policies in this region and abroad, future expansion of the facility must be considered in the planning and site orientation. The following is an outline of the program requirements for the base facility installation. All support and shipping of modules will be done by sea-air delivery. Air delivery will be provided by both fixed wing and helicopters under tactical conditions. Military personnel trained and untrained will be required to maneuver the modules on site and erect the base camp. Speed of erection will minimize casualties. The only specialized pieces of equipment are two earth movers operated by the seabees.

Site Description

I. Soils and sub-surface conditions.

1. Sand and sand-clay mixtures with inorganic clays of low to medium plasticity. Site drainage is fair to poor with flooding during the rainy season.

2. Close proximity to the site are soils with silty gravels and gravel-clay mixtures.

II. Climate - see attached LCD data for temperatures (averages and extremes), precipitation and sun angles.

III. Energy use and conservation.

The Secertary of the Navy wants the facility to optimize its energy efficiency and independence to show its usefulness toward military applications. Building orientation, complexing, shading, use of natural lighting and land elements must all be considered and incorperated into its final erection. Consideration must be given to the noise of aircraft and small arms fire when incorperating orientation for natural ventilation.

IV. Site Circulation.

1. Egress and servicing areas are orientated toward the airfield. No aircraft support services are a part of this problem.

V. Base Facility Requirements

Space requirements indicated are approximate net square feet.

a.	Berthing for 50 permanent personnel	2500 sq.ft.
b.	Berthing for 25 temporary air crew personnel	640 sq.ft.
c.	Administration	1000 sq.ft.
d.	Kitchen	600 sq.ft.
e.	Dining area	1600 sq.ft.
f.	Medical	
	ICU	400 sq.ft.
	Casualty servicing area	400 sq.ft.
	Surgical work space	300 sq.ft.
	Operating room	800 sq.ft.
	Storage/linen area	200 sq.ft.
g.	Work shop	500 sq.ft.
h.	Storage	500 sq.ft.
i.	All purpose (laundry)	500 sq.ft.
j.	All purpose (recreational)	500 sq.ft.
k.	Sanitation and wash facilities	640 sq.ft.

1. 10 - 12 lavatories
2. 10 waterclosets
3. 10 urinals
4. Shower facility: 20 shower heads

Local Climatological Data

Annual Summary With Comparative Data

1982

GUAM, PACIFIC

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

Narrative Climatological Summary

...m is the largest and southernmost of the Mariana Islands. It lies about 13.5° N, 145° E, with ...e Philippine Sea to the west and the Pacific Ocean to the east. The Island is 28 miles long, four ...eight miles wide, and is oriented NNE-SSW. Located 1,500 miles east of Manila and 3,000 miles ...t of Honolulu, Guam serves as an important stopping place for aircraft and ships. It also has ...g been an important American military base. The population of Guam is approximately 110,000, of ...ch about half are indigenous and the remainder military and contract employees. Outside of the ...ivities of the Federal and Territorial governments, the most important single industry is agri-...ture.

...m is shaped like a bow tie, and in correspondence with this shape, there are three topographic ...ions. The northern portion of the Island is a limestone plateau that is bounded by steep cliffs ...t either fall directly to the sea or else to narrow beaches. The surface of the plateau is 300 ...600 feet above sea level. The southern portion of the Island is mountainous, with several peaks ... rise above 1,000 feet. The highest of these is Mount Lamlam which reaches 1,334 feet. The ...d major region, the narrow waist between the northern and southern regions, is quite low, being ...ally less than 200 feet in elevation.

...climate of Guam is almost uniformly warm and humid throughout the year. Afternoon temperatures ...typically in the middle or high eighties and nighttime temperatures typically fall to the low ...ties or high sixties. Relative humidity commonly ranges from around 65-75 percent in the ...rnoon to ...-100 percent at night. Though temperature and humidity vary only slightly throughout ...year, rainfall and wind conditions vary markedly, and it is these latter variations that really ... the seasons.

...e are two primary seasons and two secondary seasons on Guam. The primary seasons are the four-...th dry season, which extends from January through April, and the four-month rainy season which ... from mid-July to mid-November. The secondary seasons are May to mid-July and mid-November ...ugh December. These are transitional seasons that may be either rainy or dry depending upon the ...re of the particular year.

...ean annual rainfall on Guam ranges from around 95 inches on the windward (east) side of the ... mountains to about 80 inches along the coast of the western side of the southern half of the ... On the average, about 15 percent of the annual rainfall occurs during the dry season and 65 ...nt during the rainy season.

...l times of the year the dominant winds on Guam are the trade winds which blow from the east or ...east. The trades are strongest and most constant during the dry season, when wind speeds of ... m.p.h. are very common. During the rainy season there is often a breakdown of the trades, and ... days the weather may be dominated by westerly-moving storm systems that bring heavy showers ...eady, and sometimes torrential, rain. Occasionally there are typhoons, and these bring not ...tremendous rains, but also violent winds that may cause a surge of water onto low-lying coastal ... Since 1948 typhoons have passed sufficiently close to Guam to produce high winds and heavy ... in every month, but their most frequent occurrence is during the latter half of the year. The ... having one or more typhoons pass within this distance in any particular year is about 1 in ...e chance of having a typhoon move directly across Guam, however, is only about 1 in 5 years.

...National Weather Service station on Guam is located on the western side of the northern plateau. ...ean is 1-1/2 miles to the west, nine miles to the north and east, and five miles to the south-... The weather instruments at the station are well exposed in the center of an open field that ...acres in area. The trade winds reach the station after rising sharply up the 500-foot cliffs ...e eastern side of the Island and flowing nine miles on an easy downslope grade across the ...t of the northern plateau.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION · NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE · NATIONAL CLIMATIC DATA CENTER ASHEVILLE, N.C.

Meteorological Data For The Current Year

Month	Daily maximum	Daily minimum	Monthly	Highest	Date	Lowest	Date	Heating degree days	Cooling degree days	Water equivalent Total	Greatest in 24 hrs	Date	Snow, Ice pellets Total	Greatest in 24 hrs	Date	Relative humidity Hour	Hour	Hour
JAN	86.8	67.9	77.4	86	24	66	23	[illegible]	375	2.92	1.13	16	0.0	0.0		76	74	[illegible]
FEB	83.2	70.1	76.6	86	3	63	26	[illegible]	[illegible]	1.77	1.06	1-2	0.0	0.0		[illegible]	76	69
MAR	84.5	70.3	77.4	86	29	65	14	[illegible]	370	2.44	0.50	30	0.0	0.0		76	72	85
APR	86.8	70.0	78.7	89	30	65	10	[illegible]	408	0.99	0.44	3-4	0.0	0.0		69	68	87
MAY	86.8	72.7	79.6	[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	4.35	2.10	16-17	0.0	0.0		[illegible]	74	87
JUN	86.9	72.7	79.7	[illegible]	15	67	[illegible]	[illegible]	[illegible]	6.77	4.21	22-23	0.0	0.0		77	77	92
JUL	85.8	72.4	78.8	89	[illegible]	[illegible]	[illegible]	[illegible]	412	13.61	4.15	19-20	0.0	0.0		82	[illegible]	94
AUG	85.6	71.6	78.6	94	27	67	[illegible]	[illegible]	[illegible]	6.32	1.52	1-2	0.0	0.0		87	80	91
SEP	85.3	[illegible]	[illegible]	[illegible]	29	[illegible]	[illegible]	[illegible]	[illegible]	27.13	4.66	6-7	0.0	0.0		83	82	93
OCT	[illegible]	[illegible]	[illegible]	[illegible]	16	[illegible]	[illegible]	[illegible]	[illegible]	11.86	3.49	3-4	0.0	0.0		79	81	94
NOV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.37	4-5	0.0	0.0		82	74	92
DEC	83.1	71.5	77.3	84	29	63	31	0	389	6.33	0.79	1-2	0.0	0.0		80	78	83
YEAR	[illegible]	[illegible]	[illegible]	[illegible]	JUN	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.66	SEP 6-7	0.0	0.0		[illegible]	77	[illegible]

Normals, Means, And Extremes

Month	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating degree days	Cooling degree days	Normal precipitation	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs	Year	Snow, Ice pellets Maximum monthly	Maximum in 24 hrs
(a)				25		25					26		26		26		[illegible]	[illegible]
J	85.2	71.5	77.1	87	1978	[illegible]	1970	0	[illegible]	[illegible]	23.39	1976	1.29	1966	6.26	1976	[illegible]	[illegible]
F	83.3	71.3	[illegible]	88	[illegible]	59	[illegible]	0	[illegible]	[illegible]	14.72	1980	0.67	1967	9.24	1980	[illegible]	[illegible]
M	84.5	71.0	[illegible]	[illegible]	1955	55	1965	0	[illegible]	[illegible]	16.94	1971	0.59	1965	3.55	1972	[illegible]	[illegible]
A	85.6	72.5	79.0	90	1963	59	1965	0	421	[illegible]	19.55	1963	0.50	1965	6.37	1974	[illegible]	[illegible]
M	86.4	73.1	79.4	91	1971	62	[illegible]	0	456	[illegible]	40.13	1976	0.90	1959	27.00	1976	0.0	[illegible]
J	86.7	72.9	79.8	91	1975	63	1972	0	[illegible]	5.19	11.53	1958	1.52	1960	4.55	1958	0.0	[illegible]
J	86.2	72.6	79.4	93	1966	66	1959	0	[illegible]	9.59	20.00	1972	4.74	1957	5.17	1969	[illegible]	[illegible]
A	86.1	72.2	79.1	91	1968	67	1982	0	437	12.16	25.66	1974	3.47	1965	7.81	[illegible]	[illegible]	[illegible]
S	85.8	72.4	79.1	95	1957	61	1954	0	[illegible]	[illegible]	27.13	[illegible]	6.79	1969	7.49	1965	[illegible]	[illegible]
O	85.6	72.3	78.9	91	1957	64	1962	0	437	14.40	26.05	1979	6.63	1976	12.14	1979	[illegible]	[illegible]
N	85.3	73.2	[illegible]	89	1950	62	1957	0	426	8.51	18.16	1957	[illegible]	1973	7.26	1957	[illegible]	[illegible]
D	84.1	72.9	78.5	89	1966	61	1980	0	415	5.85	16.19	1963	2.22	1977	6.07	1963	[illegible]	[illegible]
YR	85.1	72.3	78.7	95	SEP 1957	54	MAR 1965	0	[illegible]	[illegible]	[illegible]	MAY 1976	0.50	APR 1965	27.00	MAY 1976	[illegible]	[illegible]

(a) Length of record, years, through the current year unless otherwise noted, based on January data
(b) 70° and above at Alaskan stations
* Less than one half
T Trace

NORMALS - Based on record for the [illegible] period.
DATE OF AN EXTREME - The [illegible] of multiple occurrences.
PREVAILING WIND DIRECTION - Record [illegible]
WIND DIRECTION - [illegible]

Average Temperature

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual

Heating Degree Days

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total

Cooling Degree Days

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total

Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual

Snowfall

Season	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total

692 Professional Study - Listing of Requirements

* Physical modeling of the basic components and building module illustrating integrated systems, concepts and structure.

* Plans, elevations, sections and axiometric drawings illustrating the details of the system.

* Two site modules illustrating the flexibility and adaptability of the building system to various sites and climate extremes.

* Energy analysis of the basic module for several climate extremes.

692 Professional Study Scheduling Sequence

September 2	Classes begin
September 2 - Ocotber 11	Component System Design
October 18	Mid-point review
October 20 - November 8	Design development and complexing design
November 10 - November 22	Presentation and final submission

APPENDIX

APPENDIX A (Table 1)

LIST OF COMMERCIAL MANUFACTURERS AND ORGANIZATIONS CONTACTED

Manufacturers Surveyed	Survey Returned and/or No Forwarding Address	Manufacturers Reporting
Dukor Modular Systems Redwood City, CA 94064	*	
Journal of Reinforced Plastics and Composites Univeristy of Stanford, CA 94305		*
National Homes Corperation Lafayette, IN 47904	*	
LCA Modular Enterprises Inc. Ft. Wayne, IN 46807	*	
Plastics in Building/Construction Westport, CT 06880		*
Air Structures Institute St. Paul, MN 55101	*	
Plastics in Construction Council New York, NY 10017		*
Procelain Enamel Institute Inc. Arlington, VA 27209		*
Thermal Insulation Manufacturers Association Inc. Mt. Kisco, NY 10549	*	
The Society of the Plastics Industry Inc. New York, NY 10017		*
Laminated Fiberglass Insulation Producers Association Cleveland, OH 44115		*
Construction Industry Manufacturers Association Milwaukee, WI 53202		*

Manufacturers	Survey Returned	Responding
Construction Engineering Research Laboratory Champaign, IL 61280	*	
Facilities Engineering Support Agency U.S. Corps of Engineers Fort Belvoir, VA 22060		*
Cold Regions Research and Engineering Laboratory Hanover, NH 03755		*
Southwest Materials Advisory Board National Research Board Washington, D.C. 20418	*	
National Research Council Washington, D.C. 20418		*
Construction Research Council Washington, D.C. 20005	*	
National Association of Housing Corperations Washington, D.C. 20036	*	
Metal Building Component Manufacturers Pittsburg, PA 15238	*	
National Bureau of Standards Garthersburg, MD 20234		*
Building Research Advisory Board Washington, D.C. 20498	*	
Battille Memorial Institute Columbus, OH 43201	*	
General Electric Company King of Prussia, PA 19406	*	
Urban Systems Development Corp. Fredericksburg, VA 22401	*	

Manufacturers	Survey Returned	Responding
Manufactured Housing Institute Arlington, VA 22202	*	
Council of Housing Producers Los Angeles, CA 90069	*	
National Association of Home Manufacturers Falls Church, VA 22042	*	
National Association of Home Builders of the United States Washington, D.C. 20005		*
National Housing Conference Washington, D.C. 20036	*	
Click Systems Incorperated New York, NY 10022		*
Modular Housing in the Real Annandale, VA 22005	*	
Program in Urban and Regional Studies Uthica, NY 14853	*	
American Klegecell Corperation Grapevine, TX 76051		*
NASA Washington, D.C. 20546	*	
Imyco Incorperated Milwaukee, WI 53201		*
Alliance Wall Corperation Atlanta, GA 30362		*
National Acadamy Press Washington, D.C. 20418		*
Porta-Kamp Manufacturing Houston, TX 77008		*

Manufacturers	Survey Returned	Responding
Nordam Transportable Shelter Systems Tulsa, OK 74120		*
Goodyear Aerospace Division Litchfield Park, AZ		*

FOOTNOTES

[1] Arbert Bemis, The Evolving House: Rational Design, (MIT Cambridge, Mass: Technology Press, 1936) p.25

[2] Bemis, p.61

[3] Bem.s, p.75

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